CERAMICS

SEPTEMBER
1953

No. 55 Vol. V

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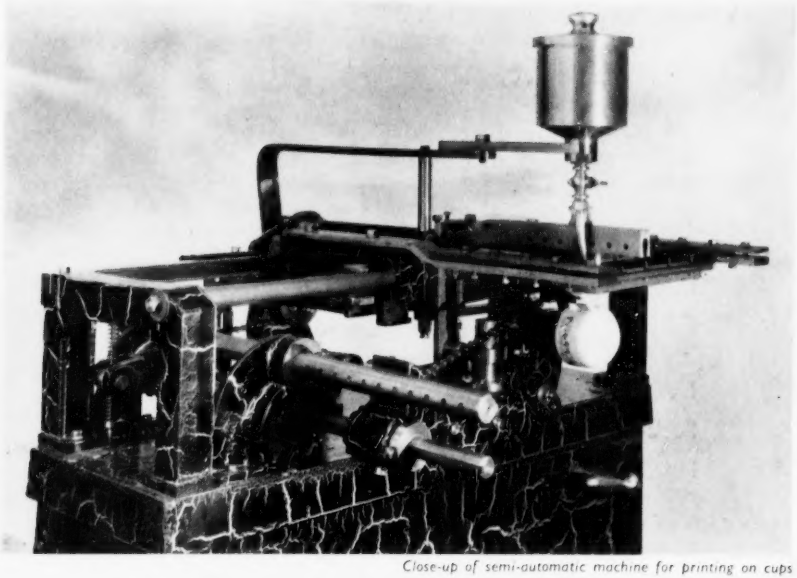

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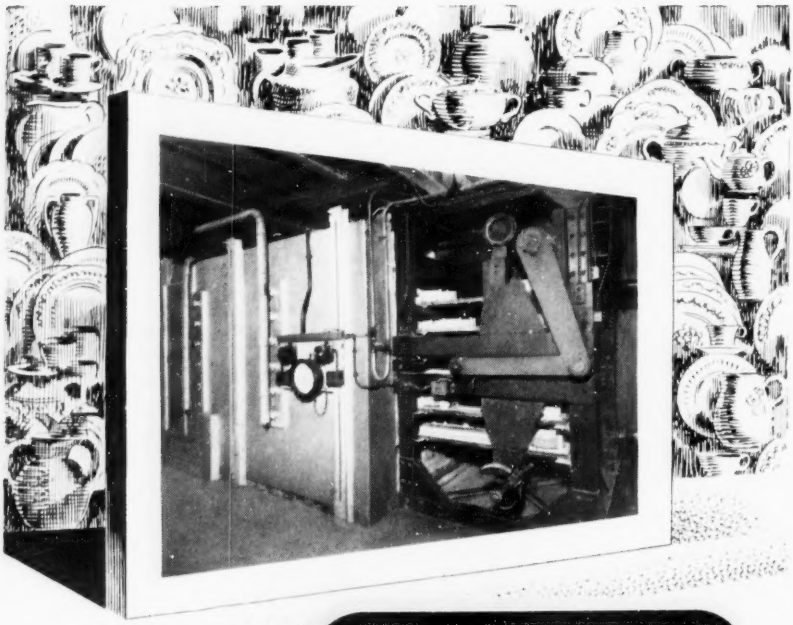

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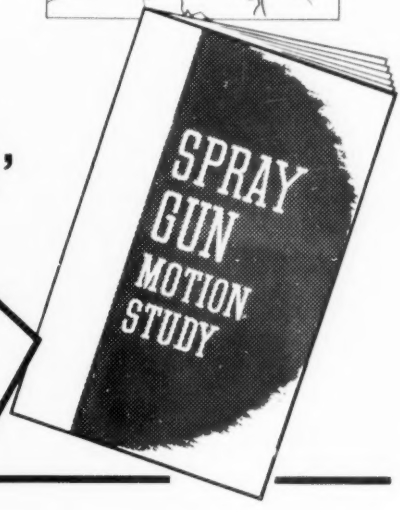

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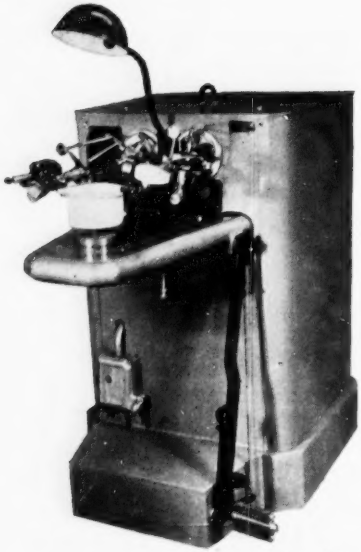

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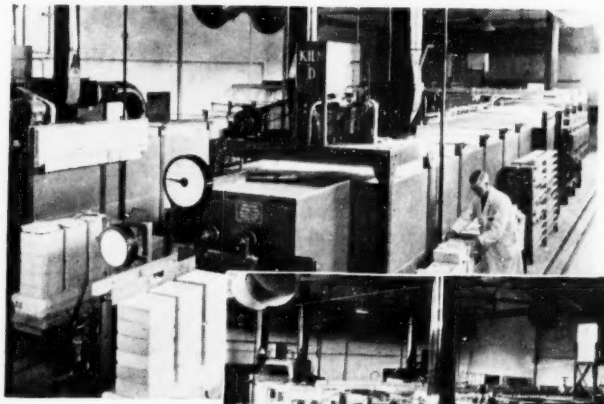

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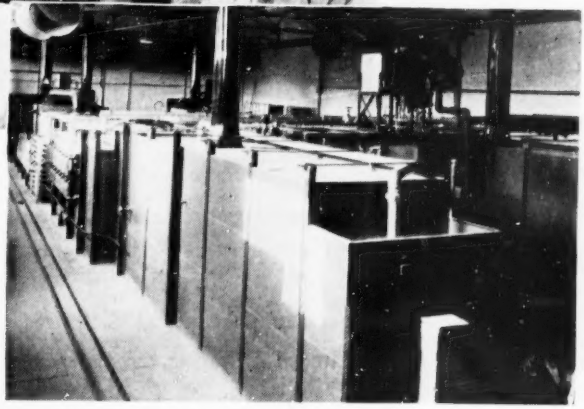

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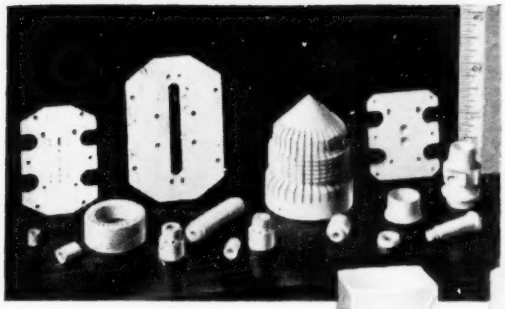

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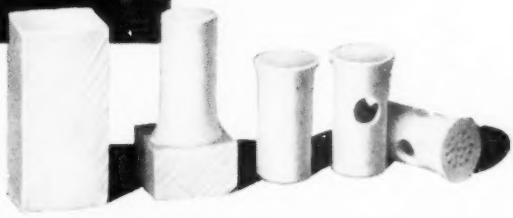

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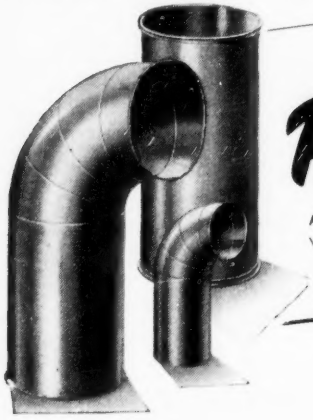

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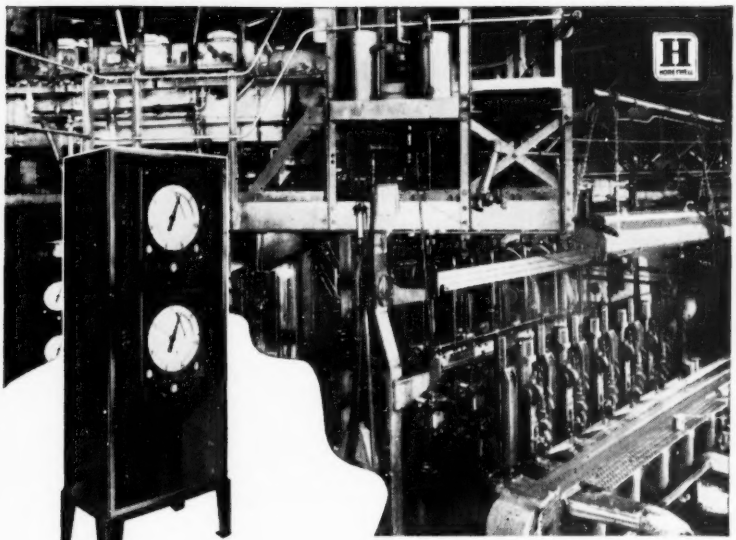

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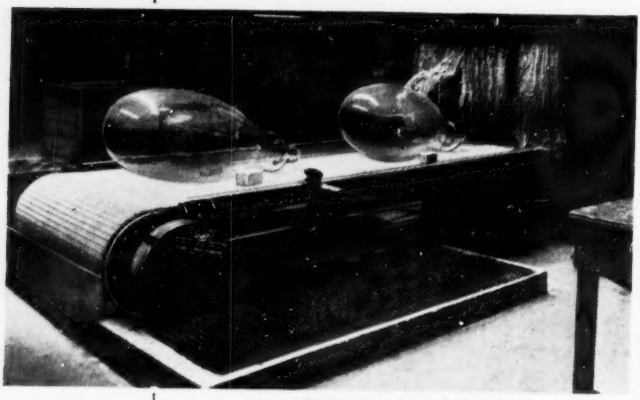

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SEPTEMBER 1953

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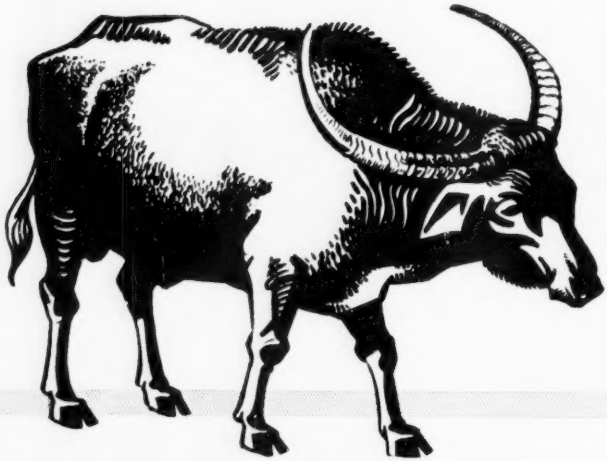

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Ceramics

VOL. V SEPTEMBER, 1953 NO. 55

FUEL FACTS KNOWN

NOW—ACTION PLEASE!

AT least one report from the Anglo-American Council on Productivity will be read avidly in the potteries—it is entitled "Fuel Conservation".

From time to time in the pages of CERAMICS we have drawn attention to the tragic fuel position facing the potteries. Ever since the war successive Ministers have praised the activities of the pottery industry. They have been praised for their export programme. Yet in terms of Government treatment and Government assistance undoubtedly pottery has been considered a "poor relation". However, one is pleased to hear from the Secretary for Overseas Trade that the Government attaches the greatest importance to the part which can be played by the consumer goods industries, including pottery and textiles in trade negotiations with overseas countries.

Fuel Costs

Yet one of the greatest problems facing the pottery industry is the rapidly increasing cost of fuel, for which they are constant consumers for seven days a week for practically fifty-two weeks in the year. They were encouraged to install expensive kilns to operate with refined fuels such as gas and electricity. The pottery manufacturers have invested millions of capital in such schemes. At the time they knew the price of fuel, but since then there has been a succession of increased fuel prices. The British Pottery Manufacturers' Federation has done yeoman work in fighting the industry's battles, so have the Chambers of Commerce, but it was of little avail.

There has been a succession of official reports on fuel, culminating in the Ridley Report. However, this Fuel Conservation Team which returned from America not so long ago did not represent the interests of coal, gas or electricity—it was very much representative of a cross-current of British industry. Thus it was free to present the facts of the case and demand action in the interests of fuel consumers and not the fuel industries.

Their Report confirmed that for the next thirty years Britain will have to rely upon coal for the vast proportion of her energy. It commented that plant using coal in Britain was out of date and was designed for those happy, or unhappy days, when coal was in abundant supply at as little as 10s. per ton at the pithead. It continued to say:

"Steam is perhaps the commodity most universally consumed in British industry and perhaps the worst used,

primarily because our traditional practice has been to divorce processing departments from engineering departments."

The Team thinks that for every 10 per cent. saved in producing steam 5 per cent. or more could be saved in the actual utilisation. It points out, however, that although our basic fuel industries have been nationalised they have never been co-ordinated. Much is talked about the so-called free competition between electricity and gas, but this is rather a farce. The Coal Board mines all the coal, the Ministry of Fuel and Power allocates the coal and the gas and electricity industries take what they can get. Competition indeed with a strange twist.

There are, of course, Consumer Councils, supposedly to protect the interests of the consumer but the important one, dealing with coal, meets in private session, the public and the press being excluded! This is hardly other than the action of an autocracy. At least the gas and electricity Consultative Councils meet in public, but if the product they use and upon which they depend is allocated in conditions of extreme secrecy they cannot reasonably tackle the cost problem. How, indeed, can the cost of gas or electricity be brought down appreciably when the electrical industry spends 70 per cent of its generating costs for coal and the gas industry spends somewhere about 40-50 per cent? What is more, the National Coal Board jealously resists any enquiry and the so-called Consumers' Council seems to work hand in hand with the Coal Board.

Power for Production

In America it is pointed out that the workman has more than three and a half times the energy at his disposal in the factory than is the case in Britain. In fact, if the unfortunate British worker merely had twice as much energy as he now receives he would consume the whole output of the British Electricity Authority! Quite obviously then, any productivity drive must pre-suppose a greater amount of electricity to be available to the factory for power purposes. Yet where, indeed, can this electricity be obtained? Already the electricity industry is consuming some 36 million tons of coal per annum. It is doubtful indeed if its allocation can be increased. There are, of course, certain fields where electricity is essential—light, power, and certain specialised processes are obvious cases in point. But that is merely part of the story.

There are places where electricity is being used disadvantageously. Is there an excuse for factories to be starved of power in order that electricity should be used for cooking and intermittent space heating, a load over which the British Electricity Authority has no control? This Productivity Team state that certain vexed questions await solution. They ask:

(1) Is it in the national interest that electricity, a costly and refined product, should be used for space heating, except where gas is not available?

(2) Is it not essential, in view of industry's future needs for power, that the functions of electricity be confined to the provision of power, light and certain specialised heat processes?

(3) Is not gas the right fuel to retain on tap for space-heating purposes (occasional heating)?

They mention that since the base load for space-heating can only be carried by solid fuel, is it not in the country's best interest that smokeless fuel be used particularly in the domestic sphere?

A Positive Note

The Team do strike a positive note for the consumer when they say that the coal, gas and electricity industries have consolidated their own policies and pursued their own line of action—"presumably because the wider national interest is none of its responsibility." It accuses successive fuel Ministers of taking no action in this matter since nationalisation.

The Team say:

"We join the great body of informed opinion in thinking that a national fuel policy is essential to the future well-being of this country."

As a result of this failure to face up to this question there has been a considerable increase in the price of fuel. Everyone knows that it is absurd to imagine that one can take coal, convert it to electricity at little over 20 per cent conversion efficiency and then waste this costly, refined fuel for a variety of

purposes which a less refined fuel would do equally effectively whilst simultaneously starving British factories of power. Because the British electrical industry has been unable to reduce its generating costs appreciably, or in other words, to increase the efficiency of coal conversion, the fuel position in Britain has been aggravated. There, again, one must, of course, remember the bad days of December and the deaths directly attributable to the burning of bituminous coal. Coal burnt directly and corresponding fog are well known in the potteries—since the change over largely to smokeless fuels the atmosphere of Stoke has improved beyond measure.

This "Fuel Conservation" Team has done a good job. The *Manchester Guardian* states "that the Report is rightly written in strong language." The *Financial Times* says: "The practical recommendations offered by the team are unexceptionable."

A Fuel and Power Board

The Anglo-American Productivity Council is now deceased and in its place there is the new British Productivity Council. Its most important job is to take over and extend the excellent work which has been done by the Fuel Efficiency Committees of the Ministry of Fuel and Power, as well as to implement the findings of the Pilkington Committee. The British Productivity Council is, therefore, now in a tight corner.

Undoubtedly fuel conservation is the most important activity facing Britain. The British Productivity Council is outside the realms of direct political control. To encourage fuel efficiency it has half a million from the Coal Board and a quarter of a million each from the Gas and Electricity Boards. What is more, the "Fuel Conservation" Team have given it a factual statement. It has asked for a Fuel and Power Board and, indeed, one feels that the British Productivity Council does have a first class opportunity of facing up to this job most effectively.

The Report says:

"Would it not be better to establish a simple, permanent and non-political Fuel and Power Board to undertake the higher direction of these three national industries, composed of men best fitted for the job?"

The first job of the proposed Fuel and Power Board would be to get on with co-ordination. Quite obviously it is in the interests of the public that some real attention is given to these matters. Increasing fuel prices cannot fail to act other than adversely upon the future of British industry. The heavy users, such as the potteries, are, of course, tremendously affected. After all, they must have copious supplies of electricity and gas, and what is more, they must have it at a reasonable price, otherwise they cannot hope to compete with Japan and Germany indirectly financed by dollars. The Secretary for Overseas Trade promises to help the pottery industry. What better incentive than to improve the fuel cost position. With the publication of this "Fuel Conservation" Report the last theoretical word has been spoken.

The team correlates and presents the evidence on British fuel which is shared by the vast majority of fuel economists and technologists, who have not an axe to grind by being on the staff of the Coal, Electricity or Gas Boards. They recommend co-ordination, and indeed it is difficult to produce any logical argument against this. It recommends a non-political body and, of course, the British Productivity Council describes itself as a non-political body. Thus it seems to be all set to do something towards this Fuel and Power Board.

British factories must have more power—the British electrical industry can hardly expect to receive any more coal, so that the only thing they can do is to divert some of the electricity they make to industry. Nor can the electrical industry hope to do much more in the immediate future on the question of increasing the efficiency with which it converts coal to electricity. Progress in the future will seem to be a succession of 1 per cents around a 20 per cent. low!

Cannot be Overlooked

Greater productivity means more electricity on the factory floor. It is one thing to say that we must get more coal, but capital investment programmes take time and it would be wrong to assume that we are going to get appreciably more coal in the immediate future. Thus, one says to the Minister of Fuel and Power that you

(*Continued on page* 321.)

The Use of Copper Compounds in Ceramic Glazes

(SPECIALLY CONTRIBUTED)

THE use of copper compounds in ceramic glazes is of great antiquity, since they were used in the beautiful blue glazes of the early Persians and Egyptians, and the copper red glazes were made by the Chinese in very early times. The Persian blue glazes were thought at one time to be coloured with cobalt ore, but Seger found by analysis that the glaze contained copper as the colouring agent and was applied over an engobe covering a red body.

The copper colours are produced as either in-glaze or on-glaze effects. It is possible to make an underglaze pale green colour containing copper by fritting a mixture of red lead, flint, felspar and copper oxide, but at the usual glost temperatures the copper compounds tend to volatilise, and the result is blistering and variable tints.

In-Glaze Effects

Copper oxide is sometimes added to glazes to produce a characteristic green colour. The exact colour is dependent to some extent on the composition of the glaze, and the temperature of the glost oven needs to be on the easy side to avoid shading by volatilisation of the copper. The colour of the final glaze tends to be a bluish green and finally turquoise blue in glazes where the alkali content (Na_2O and K_2O) is increased. Turquoise glazes tend to craze on a normal earthenware body on account of their high thermal expansion. In ordinary copper green glazes the bluish cast in the colour is counteracted by zinc and boric oxides in the glaze composition. Lime also helps to develop a yellowish tint. Alumina darkens the colour.

It must not be forgotten that copper oxide acts as a flux in glazes, lowering the maturing point, and, following the rule that materials which soften glazes increase their expansion co-efficients, tend to bring on crazing on the usual bodies. Usually not more than 3 per cent of copper oxide is added to a glaze. When larger amounts are added they dissolve in the glaze and are thrown out again on cooling. Occasionally this gives a black metallic-looking opaque glaze, which has been used for tiles for surrounds.

A glaze which has been recommended for producing a bright transparent green colour is the following:

$$\left.\begin{array}{l} 0{\cdot}15\ K_2O \\ 0{\cdot}30\ CaO \\ 0{\cdot}15\ ZnO \\ 0{\cdot}30\ PbO \\ 0{\cdot}10\ Na_2O \end{array}\right\}\ 0{\cdot}15\ Al_2O_3,\ 1{\cdot}6\ SiO_2$$

Turquoise Blue Colours

Highly alkaline glazes often give different coloured effects from those normally found in the usual glazes. Manganese oxide gives a violet colour in this way instead of the rich brown normally obtained, and copper oxide produces a rich turquoise blue colour.

For long the beautiful blue faience tiles discovered on ancient Persian and Egyptian buildings were thought to be coloured with cobalt compounds. H. Seger, however, (Collected Works, Easton, Pa 1902) showed that the glaze contained only copper as the colouring agent. The body was of red clay containing free silica, and its expansion characteristics helped to match the comparatively high expansion of the glaze. The latter was of the alkaline type, containing copper oxide as the colouring material, and was applied over an engobe. Its analysis indicated a molecular formula of:

$$\left.\begin{array}{l} 0{\cdot}12\ K_2O \\ 0{\cdot}345\ Na_2O \\ 0{\cdot}345\ PbO \\ 0{\cdot}190\ CuO \end{array}\right\}\ \begin{array}{l} 2{\cdot}225\ SiO_2 \\ 0{\cdot}204\ SnO_2 \end{array}$$

and the maturing point was 700-800°C.

Such a glaze would, of course, craze

TABLE I.
(*N. Henze, Ceram et Ver.* 49, 43, 1929)

Frit No.	*Mol. Formula*				
	Na_2O	K_2O	PbO	CuO	SiO_2
1	—	0·92	—	0·08	2·4
2	0·4	0·5	—	0·1	2·0
3	—	0·6	0·3	0·1	4·0
4	—	0·7	0·2	0·1	3·0
5	0·6	0·4	—	—	2·5 (*plus 7·9 gram CuO*)
6	0·35	0·35	0·2	0·1	3·0
7	—	0·6	0·3	0·1	1·8
8	—	0·5	0·45	0·05	2·0
9	0·3	0·6	—	0·1	2·3

on ordinary bodies, and it requires a high expansion siliceous type of body.

The conditions for producing a satisfactory turquoise blue colour or glaze have been studied in some detail by H. Hecht (Tonind Z. p. 453, 1895; Sprech **48.** 201. 1915; Ker Rund. **23.** 133. 1915), A. Granger (Ker Rund. **21.** 525, 1913. Bull. Soc. Chim. 1914, p. 115), N. Henze (Ker Rund. **36.** 821, 1928; Ceram et Ver. **49.** 43. 1929) and M. M. French (J.Amer.Cer.Soc. **6.** 405. 1923). Briefly, the conclusions were similar to those outlined above for in-glaze copper effects namely that CaO, BaO, MgO, ZnO, Bi_2O_3, Al_2O_3, B_2O_3 were all unfavourable to the formation of blue colours, tending to give green. Up to about 0.5 PbO could be added but in higher amounts green colours were formed.

M. M. French recommended a glaze made from soda ash 64, nitre 20, whiting 30, flint 168 which was fritted. The glaze formula reduced to:

$$\left.\begin{matrix} 0{\cdot}6\ Na_2O \\ 0{\cdot}1\ K_2O \\ 0{\cdot}3\ CaO \end{matrix}\right\}\ 2{\cdot}8\ SiO_2$$

To this copper oxide was added. This was used on a siliceous body, details of which were given.

These frits would suspend badly in water and would need doping to give satisfactory dipping properties.

Henze describes the addition of a little cobalt oxide to develop the blue colour, e.g., PbO 67·2, Felspar 28·8, Silica 24·0, zinc oxide 20·0, boric acid 16·0, copper carbonate 7·2, copper oxide 1·6, cobalt oxide 0·1. This was fritted and for dipping 100 parts of the ground frit were mixed with ten of china clay in water. Tin oxide improves the stability of the colour.

Copper Reds

The copper red colours are produced in reducing atmospheres, and are supposed to be due to the production of colloidal particles of copper in the glaze. The history of the copper red glaze is given by J. N. Collie (Trans. Brit. Ceram. Soc. **17.** 379. 1918). According to this authority the first mention of it is in the reign of Hsüan-Tê (1426-1435). Louis Franchet (ibid **7.** 71. 1907-8) states that the discovery of the glaze was probably the result of a lucky chance. The pieces of red-glazed ware were very greatly prized, but none of the earliest pieces have survived. The art appears to have been lost, for in the reign of Chia-ching (1522-1566) the imperial potters requested permission to decorate porcelain with overglaze iron reds. The copper red or sang-de boeuf glaze was next heard of in the reign of Kang Hsi (1662-1722) and is described in the d'Entrecolles letters in 1712 and 1722.

Production in Europe

The Chinese descriptions of the glaze were (possibly intentionally) very obscure, and it was not made in Europe

TABLE II

Frit No.	1	2	3	4	5	6	7	8	9
Silica (SiO_2)	144	120	240	180	150	181	108	120	138
Pot. nitrate (KNO_3)	186	—	—	—	—	70·7	—	—	—
Pot. carbonate (K_2CO_3) ...	—	69	82·8	96·6	55·2	—	83	69	83
Sod. carbonate (Na_2CO_3) ...	—	42·4	—	—	63·6	37·1	—	—	32
Red lead (Pb_3O_4)	—	—	68·5	45·6	—	45·6	68·5	103	—
Copper oxide (CuO)	6·3	7·9	7·9	7·9	7·9	7·9	7·9	3·95	7·9

N. Henze described a number of deep blue frits based on silica, pot. carbonate or nitrate, soda ash and copper oxide, with or without additions of red lead. The formula of these are given in Table I, while Table II gives the recipe.

until towards the end of the 19th century. H. Franchet (loc. cit) quotes an analysis made by J. J. Ebelmen and A. Salvetat (c.f. also J. W. Mellor Trans. Brit. Ceram. Soc. **35.** 370. 1936) of a fragment of red glaze taken from a Chinese vase which gave:

SiO_2	...	...	73·90%
Al_2O_3	...	...	6·00%
$FerO_3$	...	...	2·10%
CaO	...	...	7·30%
K_2O	...	...	3·00%
Na_2O	...	...	3·10%
CuO	...	...	4·60%

Ebelmen and Salvetat synthesised a glaze from this analysis and produced red in-glaze copper decoration for the first time in Europe, using a reducing atmosphere.

An investigation into the conditions for manufacturing copper-red glazed ware was begun at Sèvres in 1879 by C. Lauth assisted by G. Dutailly. The results were published in 1888 (Génie civil **12.** 322, 344, 359. 1888. C. Lauth. La manufacture nationale de Sèvres, p. 223. Paris. 1889). They concluded that it was important to cool quickly after reduction to prevent the copper from being oxidised, giving a green glaze. This was in accordance with the practice of the Chinese who removed the ware from the oven while still hot. Franchet concluded that any glaze would give a red colour in a reducing atmosphere provided it contained copper. The composition of the glaze affects the depth and brilliancy of the colour and the ease with which it is obtained.

Importance of Tin Oxide

The best conditions were obtained when the glaze contained alkalis, lead, and an amount of tin oxide greater than that of the copper compound. Franchet used a porcelain glaze containing 10 per cent of lead oxide, 3 per cent of copper oxide and 8 per cent of tin oxide. The tin oxide and copper compound could either be fritted with the rest of the glaze or added as a mill addition. The finishing temperature was Cone 10. Franchet preferred to frit all the ingredients together as in this way he got more uniform results. When the copper is fritted there is no point in using anything but the oxide. When added as a mill addition copper oxalate is preferable as this decomposes giving carbon monoxide, which helps the reduction. Where the glaze was completely fritted, it was ground and applied with aid of gum tragacanth. The body was of the hard paste type porcelain maturing at Cone 10.

Firing was done in closed saggars to reduce the danger of re-oxidisation of the reduced copper. Fire was reducing until Cone 012 was reached using hard wood as fuel, the firemouths being closed. After this the firemouths were opened and the firing made oxidising with coal as fuel to Cone 10 down. The total time of firing was on an average 20 hours—8 or 9 hours under reducing conditions followed by 12 hours under oxidising conditions. If the oxidising fire was over 16 hours duration the pieces began to go green. Cooling was done quickly, and this was important. Using a porcelain oven Franchet drew the pieces 48 hours after extinguishing the fires. His losses were never greater than 3 to 4 per cent and were often less.

H. Seger's Formula

H. Seger (op. cit Vol. II. p. 733) described a method of producing in-glaze copper reds on porcelain using alternate oxidising and reducing atmospheres. Examples of his formulae are:

	Dark Red	*Light Red*
White porcelain glaze	75	70
Zettletz kaolin ...	—	5
Copper oxide (CuO)	0·15	0·5-1·0
Tin oxide	1	2
Ferric oxide (Fe_2O_3)	0·5	—
Barium frit	23·35	22·0

The barium frit had a formula:

$$0{\cdot}5\ Na_2O \} 2{\cdot}5\ SiO_2$$
$$0{\cdot}5\ BaO \} 0{\cdot}5\ B_2O_3$$

and the copper oxide and tin oxide were fritted with it under reducing conditions.

The glaze was fired under oxidising conditions to dull red heat, and then the atmosphere was made reducing until the glaze began to vitrify. After this periods of oxidising and reducing conditions were alternated until the glaze was going glossy. The firing could then be finished under either oxidising or reducing conditions.

Lower Temperature Glaze

Copper red glazes maturing at lower temperatures than the above can be used, and the presence of lead improves the brilliancy. The following glaze matures at 1,000° C, and gives a good in-glaze copper red if firing is done under reducing conditions in the manner previously described:

Frit		*Mill Mix*	
Borax	45	Frit	90
Soda ash	12	White lead	10
Nitre	10	Tin oxide	7·5
Whiting	10	Copper oxide	1
Flint	70		

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Attempts at Producing Copper Reds in Oxidising Fires

Attempts at producing copper reds by including a reducing agent in the glaze mix have been made by A. E. Baggs and E. J. Littlefield (J. Amer. Ceram. Soc. **15**, 265, 1932). The material used should decompose only slowly, producing the reducing conditions at the required temperature. Silicon carbide was the material chosen since this slowly oxidises at temperatures between 1000 and 1140 C giving carbon monoxide, which acts as a reducing agent

$$2SiC + 3O_2 \rightarrow 2SiO_2 + 2CO$$

It was added to a leadless glaze containing a copper compound and tin oxide, and the glaze fired oxidising throughout. Unfortunately the oxidisation of the silicon carbide produced bad blistering in the glaze.

On-Glaze Copper Reds

A more modern technique, and one that is less troublesome to carry out—though the effects are not as fine—is the production of on-glaze copper reds (rouge flambé).

In this process the glaze is first fired on the ware in the ordinary way. It is then covered with a paste made from clay and containing a copper compound. Simple mixtures of red clay with 30 per cent of added copper carbonate have been used, but a rather more refractory clay mixture must be used if the clay shows any tendency to stick to the ware after firing.

The addition of china clay or ground shards to the clay is often adopted, and such mixtures as 60 per cent red clay, 10 per cent china clay or shards, and 30 per cent china clay or shards, and 30 per cent copper carbonate are used. This is made into a paste with water and painted on the glaze. After drying, the coated ware is heated in a muffle kiln to 650-700 C, and reduced with coal gas for 5-10 minutes. Heating is discontinued and, when cold, the clay is washed off the ware. The exact temperature and duration of the reduction to give the best results with a particular glaze needs working out by a few trials.

Should the clay crack on drying an alligator hide effect can be obtained, and the remedy is to add more china clay or shards to the mixture. Uneven temperatures will give variable tints, and so can variations in the atmosphere, especially if anything prevents free circulation of the reducing gas.

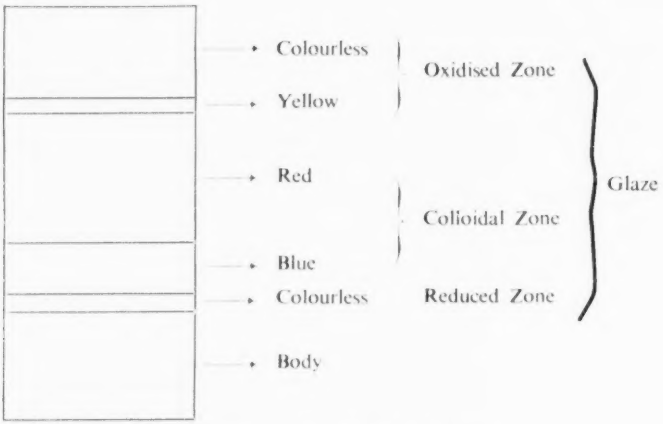
If the copper clay paste is painted on with a brush—red designs can be produced on a white background. Using a soft lead glaze it is possible to reduce the glaze itself, and thus produce red patterns on a black background—a quite pleasing result.

Chemistry of Copper Red Glazes

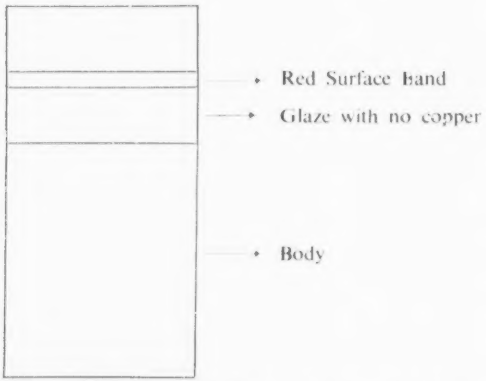
The late Dr. W. J. Mellor (Trans. Brit. Ceram. Soc. **35.** 364; **35.** 487. 1935-36.) wrote two papers on the chemistry of the Chinese copper-red glazes. He prepared photomicrographs of sections through the in-glaze and on-glaze copper reds. The results are indicated diagrammatically in the accompanying illustration.

The in-glaze effect showed several distinct layers. Immediately above the body was a colourless reduced zone. Moving outwards towards the surface a blue and red zone were noted, referred to as the zones containing colloidal copper. The oxidised zone above this contained a narrow yellow zone and a clear colourless layer.

The colourless reduced layer next the body is probably a solution of cuprous oxide (or possibly copper in



Section through Copper In-Glaze Red. (after W. J. Mellor)



Section through On-Glaze Copper Red (after W. J. Mellor)

the glaze). The blue layer represents a stage in the formation of red colloidal copper particles. By analogy with colloidal gold particles, which are known to give different colours with different particle sizes, it is probable that the blue and red layers represent different sizes of colloidal copper particles—the red being the more highly dispersed. The tin oxide probably stabilises the particles as it does in the case of purple of Cassius. The amounts of copper required to produce the colour are very small—the same thing has been noted with gold colours and with dispersed chromium oxide in the chrome-tin pinks. The thin layer of yellow above the red is taken to be due to copper particles in a finer state of division than the red ones. We thus have the transition from yellow to red to blue as the particles increase in size. This is in line with observations made with colloidal gold and silver particles. The colourless layer at the surface is a solution of cupric silicate, formed by oxidation of the colloidal copper. The amount of copper present is insufficient to give the characteristic green tint. The actual mechanism of the change is either the reduction of cupric and stannic oxides to the 'ous forms, followed by interaction forming copper

$$SnO + Cu_2O = 2Cu + SnO_2$$

or possibly some of the stannous (or ferrous present as impurity) oxide is first oxidised, and then catalyses the above reaction.

The on-glaze copper red is a more simple affair. It consists of a layer of colloidal copper produced by condensation as an aerosol from the vapour state. Similar effects can be obtained by exposing a glaze to the vapour of copper chloride in a reducing atmosphere. The clay contains the vapour and makes it easier to obtain a uniform deposit of copper on the ware.

Being a surface effect the red colour is destroyed comparatively easily by heating in an oxidising atmosphere.

NORTHAMPTON POLYTECHNIC

The Prospectus is now available of part-time courses at the Northampton Polytechnic in pure and applied chemistry, and leaflets are available to cover the University Degree in Engineering, B.Sc.(Eng.), Mechanical Civil and Aeronautical Engineering, Electrical Engineering, including Telecommunications, Applied Physics and Mathematics, Pure and Applied Chemistry, Instrument Engineering, Production Engineering, Ophthalmic and Dispensing Optics, and Watch and Clock Repairing.

Particular attention is drawn to the courses leading to the Associateship of the Royal Institute of Chemistry and the Licentiateship and Associateship of the Institution of Metallurgists, as well as courses in fuel technology, metal finishing and chemical engineering.

Of particular interest also will be a course of twelve evening lectures on refractories by L. R. Barrett, M.A., B.Sc., M.S., A.R.I.C., M.Inst.F., on Tuesday evenings at 7 p.m., commencing on September 29th, 1953.

In addition there is a course of eight evening lectures on "Chemical and Metallurgical Thermodynamics" by Dr. O. Kubaschewski, on Wednesday evenings at 7.30 p.m., commencing on September 30th, 1953.

Full details of all courses are available from the Secretary, Northampton Polytechnic, St. John Street, London, E.C.1.

The Late Mr. G. E. Barlow.—The death is announced, at the age of eighty, after a short illness, of Mr. George E. Barlow. Mr. Barlow was chairman of Hudson and Middleton Ltd., and a founder member of China and Earthenware Millers Ltd., of which he became managing director, and later chairman. He was also a director for more than twenty years of the Liverpool Borax Co. Ltd.

Paper from Glass Fibre.—Paper made from glass fibre, now being produced in America by the Owens-Corning Fiberglass Division, offers a wide variety of industrial uses. Being non-combustible and inorganic, and having high temperature resistance and excellent electrical-chemical properties, the new product lends itself to such uses as: filtration of hot or corrosive air, gases and liquids; as base sheets in electrical laminates; as gasketing material, and as plate separators in special batteries.

PRODUCTION CONTROL*

by

J. LEE

WHETHER in a large factory or a small it is of major importance to efficient running that production shall be so organised as to lend itself to control in some form or other.

By this I mean that unless there is a definite laid down scheme for Order Production, controlled from a central production office in possession of all the necessary information, then the machinery to enable organised control is just not available.

Before we consider an Order Production Scheme, however, let us rather broadly consider the main objective of any pottery organisation.

I think it will be agreed that the primary aim should be, the quickest possible delivery of orders on hand to facilitate repeat orders, thus enabling a larger turn-over within the year and a corresponding increase in profits.

May I suggest that the ideal set up to acquire this end would be to build up well planned glost finished stocks to enable immediate delivery. The factory then would, of course, be wholly employed on bulk lots to replace goods taken from stock.

Due to the war, the denial of decorated goods on the home market, excess of demand over supply and other reasons, this ideal state of affairs is not yet a fact, but it certainly seems now that the question of delivery will very shortly be a very important factor in the competitive market. In the home market particularly, customers are no longer prepared to order from a sample with the prospects of having to wait some months for delivery.

If, however, due to lack of space it would not be possible to build up glost stocks, then in any factory making a large number of items it is of major importance that good, well balanced stocks should be held in the biscuit state.

It is a proved fact that where goods are available in the bisque stock promises for delivery can be more accurately assessed, and necessary switches to avoid bottlenecks in the production line can be executed speedily at the request of the production office.

These advantages are not available where stocks are not kept in either bisque or glost. We are all aware of the numerous hazards which can arise as a result of planning from the clay stock.

At this point I would like to review the advisability or otherwise of stocks, either glost or biscuit, and endeavour to throw a new light on this problem.

So often it is said by management, particularly directors of any large factory not in close contact with the situation, that stocks at any point, are money lying idle. This to me would seem to a very short-sighted policy, bearing in mind firstly that the goods are there for immediate delivery, secondly, they should be considered as a form of insurance against normal production difficulties.

In some process departments where small staffs are normally sufficient, absenteeism and illness can be a serious hold up to production and if this can be anticipated in the form of stocks, then the bottleneck can be eliminated over a longer period of time and without panic. I am thinking particularly of banders, liners, edgers, dippers, where the absence of perhaps one operative can mean a high per cent. decrease from the particular department. A temporary breakdown in the glost tunnel oven might even be over-ridden without any serious effect to the packing.

Similarly the bisque stocks can be a

* *A talk given recently to the British Pottery Managers' and Officials' Association, Stoke and Hanley Branch.*

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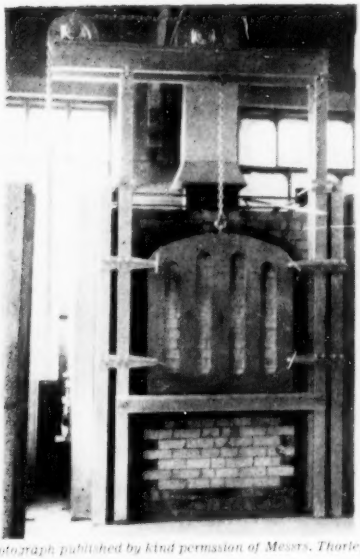

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like cover for similar possibilities in the making departments. Departments where small staffs are the necessity, such as (a) Dishmakers, (b) Pressers, (c) Holloware Jolliers, or the temporary shortage of raw materials (possibly due to lack of storage space) or a breakdown in the firing arrangements.

When planning stocks—either bisque or glost—particular thought must be given to these factors and where practical they should be anticipated and allowed for accordingly.

In the interests of quick delivery it is of extreme importance that the production of most departments should be adjustable to changing demands and circumstances.

It often happens, particularly where there is no production scheme in operation, that the factory set up has become fixed and the business controlled by the static set-up, instead of the more desirable state of the order books controlling the factory.

I am fully aware of the difficulties which this state of affairs can introduce but if we are aware of the over-all picture a lot can be done in this direction.

Having up to this point set out the ideals, let us now consider some scheme which will help to fulfil some of the needs or information as required to this stage.

Obviously any production scheme will need to be fitted into the pattern of the particular factory although there is no reason why the basic principles should not be universal.

To begin with we will assume that the glost stocks are an existing part of the organisation although in actual fact this need not be a decisive factor.

Incoming orders should be examined by some person with the necessary knowledge, to ensure that all details are recorded in factory sizes and decoration, numbers and shapes. This is necessary in order to obviate variance in the interpretation of customers' requirements by inexperienced personnel in the factory.

Orders should then be typed and if necessary broken down into different order sheets, where different patterns or shapes are controlled by different warehouses or warehousemen.

Order sheets must bear the following information:

(a) Requested delivery date.
(b) Cross reference to goods in other warehouses for same consignment.

Order sheets should be made out in triplicate, for

(1) Office Records,
(2) Production Office,
(3) Glost Warehouse order book.

Having reached the production department the following information will be extracted and recorded:

(a) Number of dozens of each particular pattern.
(b) Breakdown of orders into plates, cups, saucers, etc., of each particular shape.

The order will then be indexed in a master index book and the sheet filed.

From these records we should be able to discover the following vital and necessary information.

(1) Dozens on order of any particular pattern.
(2) Dozens on order for any particular department.
(3) Dozens on order for painting either U/G or O/G.

and for the making department.

(1) Dozens on order for any particular maker or makers or department.

We will come back to the more important functions of this department later, and just to maintain the sequence let us follow through the procedure of the order processing.

As required by the various departments on the factory, batches of a convenient size will be condensed by the production department to a set plan, which is usually,

(1) Priority orders as notified by the sales department, or as shown by records.
(2) Oldest outstanding orders.

At this stage the condensation will be passed to the bisque warehouse manager to be taken from stock and entered for further action to the next department. This entry should remain with the order through successive departments in order that a thorough check may be made if necessary.

At the same time lists of customers' orders contained in the particular batch should be passed to the sales department and the glost warehouseman in charge. In addition, his order book should be date stamped to indicate that the order has commenced its progress.

By this means the sales department can assess an approximate delivery

date and the glost warehouseman will know which orders to work on.

This sounds simple enough, but success is very dependent upon the co-operation of all departments.

In my experience the number of people on any factory who accept the packing figures as a personal responsibility are very few indeed. Most departments and foremen or women are too much inclined to adopt the attitude of isolation and to want to run their departments with the least interference and the most comfort. For the success of any scheme it is essential that batches should move complete through all departments and departmental heads should be made responsible for the necessary organisation to this end.

If this is done it will ease the burden of the warehouseman and enable him to check his orders and arrange replacements quickly.

The advantage of the glost warehouseman being instructed by the production department is obvious. All requests and information being passed to the production department, then instructions issued therefrom, are either at the original request of the sales department for some particular important reason, or are the oldest orders on the books.

Having outlined the functions of the production department as far as orders are concerned, let us now consider its additional and bigger responsibilities as far as the factory organisation is concerned.

As the production department will be in much more day-to-day contact with the making departments and the bisque warehouse, it should be situated convenient to this section of the factory and its functions as it effects this section should be as follows:

(1) Entry of orders for making in accordance with orders received and to maintain biscuit stocks.
(2) Entry of orders to mould-making department and control of priority as required by circumstances.
(3) Recording of statistics to do with making departments in relation to biscuit firing.
(4) Liaison with clay manager regarding increase or decrease in departmental production as necessary to changing conditions.

This, generally speaking, covers the day-to-day routine duties of the department but does not explain how major changes in production policy can be determined.

However, from the records now available a true and complete picture of the state of the order book in all its various patterns and departments can be extracted, a study completed, and attention attracted to any hold-ups, bottlenecks in production, or accumulation of orders for particular designs. In the form of a report this can then be presented to the management, and after a discussion by the managers concerned the production can be reorganised in the light of this up-to-date information and to over-all advantage.

To sum up there are several import-

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ant factors, all of which have a bearing on the above.

(1) It has already been said that departmental foremen dislike what they consider to be interference in the form of changes of policy. I would suggest that at any conference where a change of policy is to be discussed, all departmental heads should be present so that they may be fully acquainted with the necessity, and my experience has been that their co-operation is made available with much more enthusiasm than is effected by a formal typed instruction.

(2) Changes of policy should only be effected perhaps two or three times a year, to create the minimum interference. In any case, it sometimes takes a couple of months for some changes to become effective.

(3) Extreme measures should be taken to eliminate bottlenecks as they occur in the production line, particularly where it is likely to affect other departments. A period of overtime is often sufficient, and the extra wages in a lot of cases is an attraction. Here again, explain the difficulty and solicit co-operation.

(4) The advisability of production bonuses is a debatable point, but human nature being what it is, it is true to say that although staff may already be doing their best with an added incentive their best can often be improved.

(5) Glost warehousemen in charge of orders books should be kept informed of their packing results. A pat on the back when figures are good or an enquiry when bad is never out of place. At the same time we must remember that the packing results are the direct responsibility of all departmental heads and the management. The glost warehouse staff can only pack what comes from the oven or kilns.

(6) We must be very careful not to become slaves to factory statistics, but used wisely and intelligently as a guide we cannot successfully function without them.

STEAM JACKETED MIXING PANS

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FOR the first time a steam jacketed mixing pan has been made independent of auxiliary power for driving the mixing gear. Up to the present these mixing pans, used through trade and industry, have had the mixing gear driven by electric motor, line shafting, or even petrol and diesel motors. Such drives are now superseded by a new development of Cannon (CP) Ltd. of Bilston, Staffs, which uses the low pressure steam already raised for heating the pan to drive a three-cylinder radial steam engine mounted on the cover.

In addition to the economies of installation the new development gives several technical advantages. The steam drive provides infinitely variable mixing speeds from 1 r.p.m. to anything that will be required, and the actual mixing will be better performed.

The unit is also flame-proof, which eliminates the fire risk caused by the use of electrical motors in the many trades where inflammable mixtures are processed, and thereby reduces insurance costs. Unaffected by chemical fumes, the new stirring gear will be especially attractive to the chemical and pharmaceutical trades where many of the mixing pans are in use. The plant works normally under any climatic conditions, which gives it a strong claim to export trade.

By releasing the mixing pans from auxiliary drives a much greater flexibility of installation is made possible. The engine has a big reserve of power, the maintenance it requires is almost negligible and it will virtually never wear out.

The new propulsion unit is adaptable to existing plans, and users of all types of mixing pans who have steam available can thus take early advantage of the economies and improvements it makes possible.

A working plant demonstrated the new development at the recent Chemical Plant Exhibition, Olympia.

The other exhibits on the stand included a 50-gallon distillation plant with a 15 sq. ft. enamelled sectional type condenser, 25-gallon enamelled receiver, enamelled pipes and valves; a 250-gallon cast-iron enamelled steam jacketed mixing vessel; various capacities of open type cast-iron enamelled steam jacketed pans; various types of cast-iron enamelled agitators; and a variety of cast-iron enamelled laboratory equipment. In each case the enamel is a hard, grey, acid-resisting glass enamel, the most impervious surface of its type in the trade.

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TAS/CL.445

Ceramic Materials for the Construction of Engineering Parts

Where Alloys and Metals Fail in Service

by

B. L. MAJUMDER,
M.Sc., A.M.Inst.F.

(Note. This article is based on a paper presented at the Symposium on "Industrial Failure of Engineering Metals and Alloys" organised by the National Metallurgical Laboratory and held at the United Club Auditorium, Jamsedpur (India), on 5th, 6th and 7th February, 1953. The Symposium was organised with the object of gathering over-all data relating to observed failures of engineering metals and alloys, examining the inter-play of numerous factors involved therein and devising preventive measures based on practical and theoretical considerations. The technical papers were divided into two main parts, viz. (1) theoretical aspects of industrial failure of engineering metals and alloys, and (2) a study of actual service failures, including an investigation into causes and possible remedial measures.)

IN the late 1920's it was generally believed that the gas turbine was a Utopian scheme unless materials capable of withstanding high stresses at extreme temperatures could be developed. The gas temperature of 600° C., employed in present-day turbines can by no means be the practical limit for heat resisting materials. This called upon the knowledge and skill of the chemist, physicists and metallurgists all over the world to produce the extra quality metals and alloys which could stand the temperature and stresses to which moving parts of such power plants are subjected. These materials must have exceptionally high physical properties at elevated and room temperature, high stress-rupture values, good creep strength and damping capacity, considerable endurance and high resistance to corrosion and oxidation. In addition, they must be capable of being hot-worked, welded and machined without too much difficulty.

High-temperature alloys like "Nimonic 80" developed on subsequent investigations are, however, notoriously lacking in ductility and the fabrication of turbine blades by the usual forging operation becomes a very difficult operation. The wartime development of precision casting by the "lost wax" process is an outstanding achievement for the production of engineering parts like turbine blades in which close dimensional accuracy and surface smoothness are essential. The introduction of electric melting furnace and powder metallurgy is also a significant progress and yet the designers and manufacturers of gas turbines and jet engines are now considering the possible application of the refractory properties of ceramic materials and other less familiar compounds such as carbides as component parts of the power plants, enabling them to be operated at high gas temperature with increased efficiency and also making them last longer at the present operating temperatures. Above 600° C., the ceramic materials have certain inherent advantages over the metals and metallic alloys: their high melting points, low bulk density, high strength-density ratio and chemical inertness lend themselves for use as a blading material.

The search for special ceramic materials with unusual mechanical and thermal properties has led to the judicious selection of little-known oxide type and carbide type systems as possible fields of such study and throughout these developments the

approach and technique of crystal chemistry[1] has been very prominent. The properties of few of these bodies are quoted in Table I from different

TABLE I. PROPERTIES OF SEVERAL CERAMIC MATERIALS

Material	*Powder density, g.p.c.c.*	*Melting point, °C.*	*Tensile strength (tons per sq. in.) of sintered article determined at*	
			Room temp.	*1,000° C.*
Alumina	4·00	2,050	15·73	14·65
Zircon	4·72	2,430*	5·20	3·88
Zirconia	5·70	2,700	8·00	3·02
Beryllia	3·03	2,570	6·11	2·77
Sillimanite	2·80	1,810	5·38	8·48
Boron Carbide	2·51	2,350	10·25	7·10
Titanium Carbide	4·91	3,140	—	7·95
Zirconium Carbide	6·22	3,800	13·85	6·45
Magnesia	3·55	2,135	7·90	5·15
N.B.S. 4811	3·00	—	—	8·15

* Melts incongruently

sources and before discussing their use and performance in gas turbines, it may be of interest to consider the methods of precision fabricating the airfoil shape of their blades with necessary twist and surface smoothness. The choice of a technique for fabricating them partly determines the degree of porosity which, in turn, affects the physical properties of the fired body. The ease of fabrication has again a bearing on their application as part of limitations of the structural alloys is in the operations required to make and shape them.

The raw materials are of highest purity and after suitable physical treatment for imparting the necessary plasticity or green strength, the turbine components may be produced by conventional methods like slip casting or extrusion and sintered by firing to a temperature approaching the melting point of the raw materials. These methods, however, do not give the desired density and consequently the complexity of shapes such as turbine blades, bushings, nozzles, etc., are made by hydrostatically pressing the finely ground powders. Such dry pressing of carbides, borides, nitrides, etc., is however, difficult because of their high compressive strength and poor flow characteristics.[2] It has often proved satisfactory to press what would be equivalent to ingots and then to machine the pressed compact by surface grinding, turning and contour forming, making allowance for shrinkage during firing. The sintering of these articles presents further problems as the furnace temperature has, in some cases, to be maintained in excess of 2,000° C. for several hours[3] with provisions for precise atmosphere control.[4] Thus attempts to sinter a mixture of TiC and TiN even by heating for one hour at 2,000° C. in a vacuum of 2·5 microns of Hg. pressure resulted in only partial sintering of the compact. These difficulties have been overcome either by utilising the thermal conductivity of the carbides[5] when a heavy current passing through the cold compact raises its temperature by the resistance effect or by hot pressing them with a small amount of cobalt, nickel or their oxides at temperatures high enough to melt the metal binder. The process achieves sintering at lower temperatures and produces a dense body, pressed to close tolerances of ± 0·002 in. without warpage or shrinkage from heating. However, the relatively low melting metallic phase present in the body may become plastic at elevated temperatures; attempts[6] have, therefore, been made to remove this by heating in vacuum to such high temperature that all binder metal distills out.

The main requirements of the blades[7] attached to the rotor as regards high mechanical strength both at room and elevated temperatures is due to the centrifugal force and as this is directly proportional to their weights, the required strength of the light weight

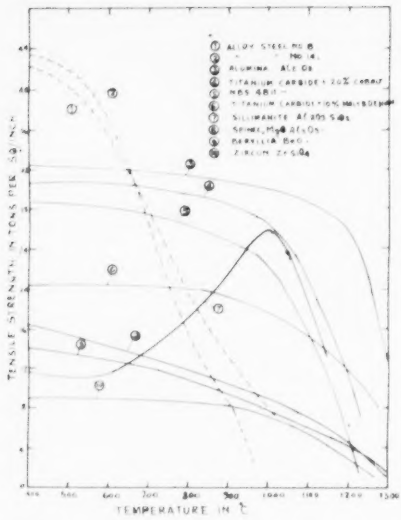

Fig. 1 Tensile Strength of Steel and Ceramic Materials at Elevated Temperature. (Equivalent strength of ceramic materials at density equal to that of metallic alloy being 8.3)

ceramic materials is considerably lower than the metallic ones. Thus, under normal operating conditions, stresses in the neighbourhood of 11 tons/sq. in. produced in a metal blade[7] will be equivalent to a stress of 3 to 4 tons/sq. in. for a low density ceramic blade. Figure 1 shows the variation of tensile strengths of several ceramic materials with increase of temperature and for a direct comparison of these values with those of the best known alloys, the strengths have been plotted on strength-density ratio. The ceramic materials do not exhibit appreciable reduction in strength until about 1,100° C. while the strength of sillimanite is maximum at about 1,000° C. owing to its phase changes on heating.[9]

Again, since the compressive strengths of the ceramic materials are of the order of ten times their tensile strength, the principles of prestressing may be applied advantageously. Thus, if the ceramic structural members are kept in compression by prestressing, they are capable of carrying much larger loads than members with no prestressing. Advantage of this prestressing was proposed by the Germans in their so-called "inverted" turbine[10] where the moving blades are mounted internally on an external rotating drum so that the forces acting on the blades produced only a bending and compressive stress. Prestressing offers further possibilities of reducing thermal and mechanical shocks, since failures from such shocks are basically tensile in nature.

Further, as the efficiences of the engines are dependent on the maintenance and dimensional accuracy of the components during service, the rate of deformation or creep of the ceramic materials under purely tensile stress at elevated temperature has recently been studied. Stress-rupture strength expressing the life of the materials in hours at a certain stress and temperature or dead loads supported by them indicate[11] that the ceramic materials exhibit greater strength (on strength-density ratio) at 1,000° C. than any heat resisting alloys.

In addition to the centrifugal stress, turbine blades are subjected, within seconds, to a very high temperature gradient—for example, by sudden starting up or shutting down as a result of failure of fuel supply. The temperature may fluctuate from that of the cold and even moisture-laden air to that of the combustion gases at 800° C. to 1,000° C. and as a result of the cumulative effects of such thermal shocks turbine blades fail by fracture through the materials, or in some cases failure may result from the action of centrifugal stress and mechanical shock after the materials had been weakened by the effects of thermal shocks.

While the tensile strengths of the ceramic materials at elevated temperatures are definitely promising, their susceptibility to fractures by thermal stress constitute a major problem and may seriously limit the potentiality of these materials in this sphere. As a general rule, high strengths, high thermal conductivities, low elastic constants and low thermal expansion contribute to good thermal stress resistance; their relationship is not, however, constant but vary with temperature. Thus, thermal stress resistance of magnesia, alumina and zirconia first decreased with increasing temperature[12] until minima were reached and then increased owing to the increased plasticity of the oxides

at that temperature. The importance of the factors contributing to good thermal resistance may further be misleading for materials which are internally stressed owing to crystallisation, devitrification or which may fail as a result of "fatigue" under very much less abrupt temperature changes than previously endured.

However, new types of materials and methods of fabrication have been developed and suitable design changes proposed to improve the thermal characteristics of the ceramic materials. Thus, a patent[13] describes the incorporation of varying quantities of combustibles in an alumina body for the manufacture of blades having layers of different porosity.

Several pure oxide ceramics may find potential applications in gas turbines[14] provided suitable design changes are made to minimise thermal shock, e.g., some protection may be assured, in the event of fuel stoppage, by automatic introduction of fuel from an auxiliary source. The series of carbide-base compositions combine the thermal shock resistance of the alloys with the high temperature strength of ceramics. During the war the Germans developed silicon carbide bodies for use as stator blades where the conditions are less drastic. The refractory carbides and nitrides crystallising with the face-centred cubic structure are the highest melting materials known and they are remarkably strong owing to the nature of their bonds between cations and the interstitial carbon of nitrogen ions. They are, however, susceptible to oxidation in varying degrees, particularly at elevated temperatures and at a gas temperature of 1,100° C. the oxidation rates of some of the carbide bodies are so high that the life of a turbine blade would be limited to about ten hours. The resistance to oxidation may be improved by the application of a suitable glaze or the incorporation of other basic materials in the compositions so that a different oxide more resistant to oxidation by diffusion processes can be formed.[15] The glazing of carbide bodies gives a very desirable smooth finish on the blade and increases their tensile strength considerably. The addition of a small percentage of columbium and tantalum carbides[16] or about 5 per cent. chromium[17] to TiC greatly increases its resistance to oxidation at high temperature.

The metals have been incorporated in ceramics for combining the most valuable properties of the metals and ceramics in a single body.[17,18] The metal phase of these "cermets" imparts some ductility and improves thermal shock resistance of the body, while the ceramic phase contributes strength at elevated temperatures. They have, however, an inherent disadvantage in that their density is higher and corrosion resistance lower than the oxide materials. The metals can be added to ceramic materials in various ways: metallic salts can be mixed with plastic ceramic materials and the product then fired, or ceramic and metal powders can be mixed, pressed and fired.[19] The less critical dimensions are usually obtained by machining or grinding of the sintered article where finished surfaces are required as in the case of turbine blade root section. Their structure and properties depend on the techniques employed in fabrication; and sintering mechanism has been studied[20] in establishing conditions which yield optimum properties. The development of infiltrating porous compacts with metal or alloy of lower melting point than that of the compact offers interesting results. Thus, the porous compacts for American TP-1 compressor stator blade pressed in multiple action die and sintered with iron powder is first machined to exact dimensions and infiltrated with a copper alloy to 100 per cent. density, and lastly heat-treated to develop the required ultimate strength of the order of 40 tons per sq. in. in tension with an elongation of upwards of 8·0 per cent.

The first attempts to use oxide-metal combination for gas turbine blades originated in Germany during the war when various mixtures of 40 per cent. to 70 per cent. alumina with iron powder (called Dug) were developed. From the mechanical strength point of view, alumina is one of the most attractive engineering materials and the Swiss high temperature alloy SAP—sintered aluminium powder—is another example. It contains 10 per cent to 20 per cent. of alumina, the balance being aluminium powder, and displays remarkable physical proper-

ties at and even above 500° C. Cermets containing 70 per cent. Al_2O_3, 30 per cent Cr, 3 per cent. to 5 per cent. Fe and 2 per cent. to 3 per cent. W have adequate strength[7] for use in jet engines at temperatures up to 980° C. or even higher; the strength is not seriously affected when this is heated in air for 100 hours at 1,500° C. and it has better thermal shock resistance than alumina. Experiments are also in progress on boride-metal and nitride-metal combinations. Thus, oxidation and physical properties of TiC-base[8] and B_4C-base[9] cermets containing various metallic constituents have been considered as another series of promising materials for rotor blades.

While high thermal conductivity was considered essential for the development of many materials, a low value of thermal conductivity may be advantageous when ceramic blades are fixed in a metal since less heat will be conducted through them. Besides, in certain applications like rocket nozzles, etc., where the heat transfer coefficient is higher and body dimensions greater, thermal conductivity is of little importance[6] for any improvement in thermal shock resistance. In such cases, improvement may be possible by developing bodies with low coefficients of thermal expansion and modulus of elasticity.[27] There are, however, indications that moduli of elasticity of ceramic materials maintain a nearly constant ratio with the tensile strength at the same temperature[28] and consequently attempts to improve the materials by altering their elastic properties are not likely to be successful.

Thermal expansion properties[29] of several ceramic materials have been compared with those of two alloys in Figure 2. Fused silica and cordierite bodies were investigated for rotor and blade units because of their low thermal expansion. However, owing to the low refractoriness and possibilities of divitrification, fused silica assembly may be used only up to a maximum operating temperature of 1,000° C. and may find stationary application where the temperature conditions are not so severe. As the cordierite porcelain first tried in the combustion chamber cracked during the initial heating, it has not been tested in actual

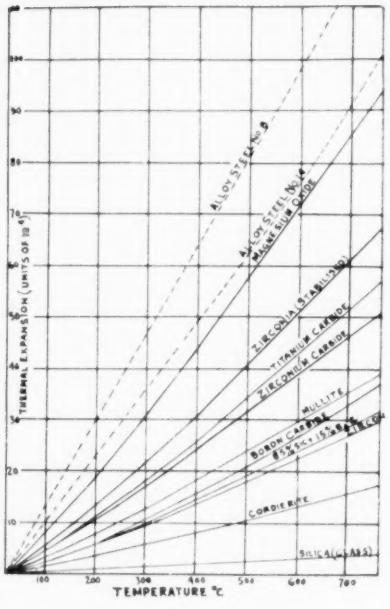

Fig. 2. Thermal Expansion Properties of typical Ceramics and High Temperature Alloys

turbine. Zircon[30] has been developed mainly because of its high refractoriness and low coefficient of expansion.

The application of ceramic coatings is attracting interest from the aircraft industry for extending the service life of jet engine components and high temperature exhaust systems for piston engines without major changes in the design of the power plants. The flexibility of steel sheet (0·002 in.) having a thin coating (0·005 in.) is comparable to that of tin foil and these sheets can be warped on to the blast tubes of jet engines; the thickness of these coatings is only about 0·001 in. to 0·003 in. in normal American practice.[31] The coatings may be applied on the metal surface by spraying like enamelling, or alternatively by deposition of refractory material from the vapour phase.[32] They resist chemical or physical changes normally occurring in the presence of flaming gas temperature; the metal exhaust systems are thus protected against any deterioration by

oxidation, absorption of carbon with consequent surface embrittlement and corrosive effects of lead bromide vapour[13] (formed by the interaction of tetra-ethyl lead and ethylene dibromide). Further, the successful performance of ceramic coated ordinary alloy steel under the ravages of jet engine environment would permit their substitution for high nickel alloys currently used and may improve thermal characteristics. However, the temperatures at which these coatings can be used have a potential limit in that the firing (maturing) temperature must increase with increased refractoriness but obviously cannot exceed the melting point of the base metal.

High temperature enamels have also been developed for protecting the tungsten metal[14] from oxidation. Zircon forms the base metal for this enamel because of its suitable thermal behaviour, resistance to slags and immunity to reaction with carbon monoxide. The excellent tensile strength and high melting point of the tungsten metal may thus be effectively used for high temperature engineering work.

A number of ceramic materials have shown better performance and tensile properties at elevated temperatures than the performance ceiling of the metallic alloys; however, there are better chances for the success of ceramic components in designs embodying ceramic stator blades[15] than those in which ceramic rotors are used. Such application in an aircraft engine will greatly reduce the weight and cost, but high inlet gas temperature may not be permissible.

Since the ceramic materials are relatively brittle or non-yielding and do not lend themselves readily to welding operations, unforseen fabrication difficulties arise in service tests; thus when the ceramic blade root is fastened into the slot of the metal disc, insufficient yielding affects the distribution of the stresses uniformly and the concentrated stress at the root may cause failure. In the case of stationary nozzle vanes, the problem can be simplified by a floating mount of some kind at each end, but this is complicated for the blades operating under high centrifugal stress. The problem may be solved by a general redesign of the root section and wheel rim. Other possible methods of solving the problem might be to use ductile metal shims between blade root and the wheel or to fabricate cermet blades with a higher metal content in the root section than the airfoil section.

It will thus appear that the best performance from the ceramic materials may be obtained by making such changes in design or operational adjustments in gas turbine as to incorporate their advantages. It is impossible as yet to predict the types of material that will ultimately prove satisfactory for gas turbines and similar applications. It seems fairly certain, however, that no one material or combination will prove to be suitable for all such applications and the choice will depend on the purpose for which the turbine is designed. For example, in military aircraft the aim is to improve the thermal efficiency by raising the gas temperature from the present limit of about 850° C. to an interim target of 1,200° C. and ultimately to 1,500° C., while at the other end of the scale, stationary power producing installations will probably derive great benefit in the first instance from the operational life to 100,000 hours.

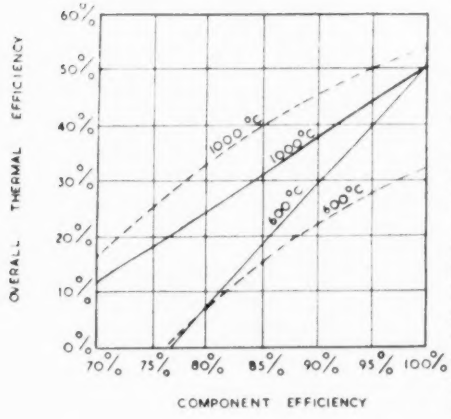

Fig. 3. ——— Simple cycle without Heat Exchanger. — — — — Simple cycle with Heat Exchanger. Variation of overall efficiency with temperature and component efficiency (after Roxbee Cox, Howell and Smith, World Power Conference, 1947. See C.2. Paper No. 7)

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TECHNICAL INFORMATION ON GERMAN INDUSTRY

READERS may like to be reminded that the technical Information and Documents Unit of the Department of Scientific and Industrial Research has published the following reports of interest, which may be borrowed from the Unit without charge or obligation:

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Department of Scientific and Industrial Research, Technical Information and Documents Unit, Cunard Buildings, 15 Regent Street, London, S.W.1.

A Fine Savings Record. Employees of Steatite and Porcelain Products, Ltd. of Stourport-on-Severn, have saved £80,000 since 1948 through their National Savings group, which now has a membership of 100 per cent. of the 900 workers. Mr. W. J. Hume, a member of the Stourport-on-Severn Savings Committee, supervises the firm's savings organisation and is assisted by Mr. E. J. Bees.

SOUTH AFRICAN NEWS

Death of Col. T. W. Cullinan

The death occurred in Johannesburg on June 9th of Col. T. W. Cullinan, managing director of the Consolidated Rand Brick, Pottery and Lime Co. (Pty) Ltd., of Olifantsfontein, Transvaal.

Colonel Cullinan, who was 66 at the time of his death, was the eldest son of Sir Thomas Cullinan, after whom the Cullinan diamond was named.

New Plant for Ceramic Manufacturers

Following a visit to Europe and the United States by one of its directors, Mr. J. F. Hoseck, the South African Glazing Co. (Pty) Ltd. has begun the erection of a modern clay preparation plant at its Boksburg factory. Modern machinery is being imported from overseas which will enable the company to produce quality porcelain ware.

"Stalton" Blocks made in South Africa

The Vereeniging Brick and Tile Co. Ltd. is manufacturing under licence prestressed burnt clay blocks for use in floors and lintels using the "Stalton" system. A new factory has been erected and equipped with pre-stressing tables.

A good deal of the machinery has been imported from Switzerland and the rest of the plant has been made locally to the design of the Vereeniging Brick and Tile Co.

First supplies of the new floor blocks were available in August, while stocks of lintel blocks have been ready some months.

Ceramic Strainer Cores made in Union

Tests having proved encouraging, the South African Glazing Co. (Pty) Ltd., of Boksburg, is to proceed with the manufacture of refractory strainer cores in fairly large quantities at reasonable prices.

Japanese Pottery Coming into Union

Luxury articles which are on the prohibited list are coming into South Africa from Japanese manufacturers. This is being done by taking advantage of two different sets of Union Government regulations.

According to import regulations, china ornaments and vases are on the prohibited list, but they are being exported from Japan as "utility" articles. Vases are coming in as celery holders, figurines as salt cellars, and so on.

The attention of the Customs Department and of the Price Controller has been drawn to what is happening, and a closer watch is to be kept on imports of china and earthenware from Japan.

Pilkingtons Add to Range

Pilkington's Tiles (South Africa) (Pty) Ltd., of Meyerton, Transvaal, have recently added to their range two new shades in glazed coloured tiles for interior wall use. They are to be followed up with further new colours and finishes.

In addition to the Union market, Pilkingtons, who established themselves at Meyerton in 1950, export tiles to the Rhodesias and Portuguese East Africa. The company digs its own clay at Koster and Kaalfontein, both places in the Transvaal while clay is also obtained from Brackenfel in the Cape.

New Cape Town Pottery Firm

Some excellent decorative and ornamental pottery is being turned out by Zaalberg Potterij (Eds) Bpk., of Parow, in the Cape. There has been a big demand for this Zaalberg pottery, which is sent direct to the retail shops from the factory. New machinery is expected to arrive from Holland soon to step up production of utility lines.

Resoweld Being Made in South Africa.

Resoweld, a self-drying protective coating for exterior application to metal tanks, structures, beams, concrete and wood, for protection against corrosion due to spillage, acid fumes or oxidation, is now being made in the Uitenhage factory of the Goodyear Tyre and Rubber Co. (S.A.) Ltd.

FUEL FACTS KNOWN.—(*Continued from page* 301.)

are unfortunate! You have succeeded a long line of Ministers all of whom did nothing, but they were fortunate enough in being able to avoid the issue. In turn they have pigeon-holed the Simon Report, the Egerton Report and the Ridley Report. Now comes a Report from industry, the fuel customer indeed, and this cannot be overlooked. The conclusion of the Report is:

"The spear head of a national campaign of fuel economy should be effective co-ordination of the fuel and power industries in terms of strategy of development and conformity to national policy."

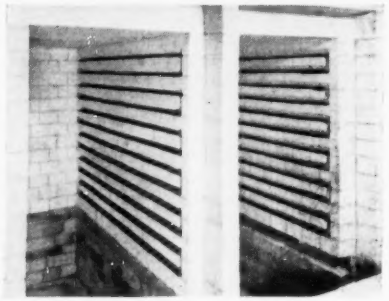
It is time to get on with this job.

NEW ELECTRIC DECORATING KILN

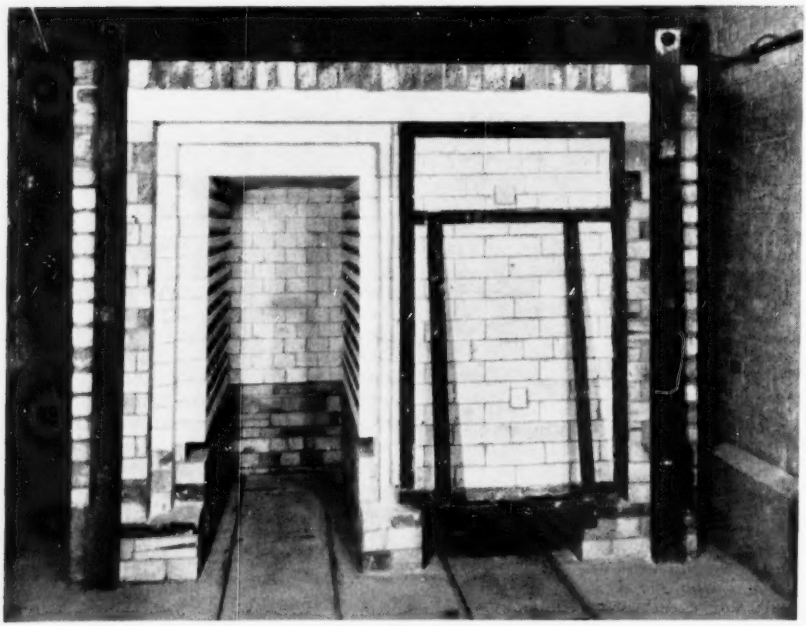
A NEW type of intermittent, electrically-fired pottery decorating kiln, developed by the Midlands Electricity Board in co-operation with a Longton, Staffordshire, pottery firm, has proved so successful after extensive practical tests that one of Britain's largest kiln manufacturers has decided to produce a range of kilns of similar design.

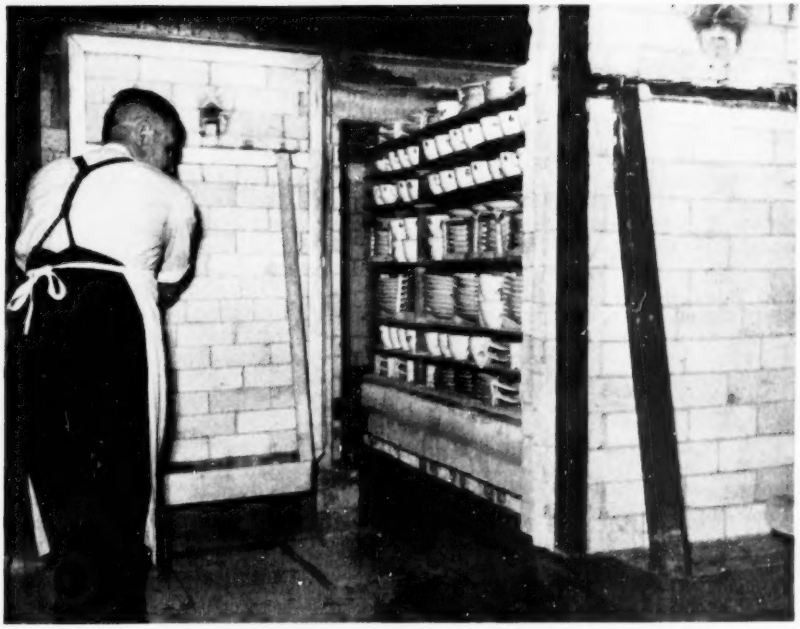
Experiments are also being made to see whether the kiln can be adapted for glost and china biscuit firing.

The new decorating kiln was designed by Mr. S. Scholefield, a member of the staff of the North Staffordshire sub-area of the Midlands Electricity Board specialising in the application of electricity to the pottery industry, with the co-operation of Mr. Spencer Stevenson, managing director of Spencer Stevenson and Co. Ltd., of Chelson Street, Longton, who arranged for a prototype installation in the course of reorganisation of the factory's firing methods. Mr. Stevenson



Below. The installation comprises a pair of rectangular kilns, set side by side, and used alternately. Right. Close-up showing arrangement of electric elements





Each kiln is fed by a truck running on rails and the kiln door is built in firebrick on the truck

sought the aid of the Midlands Electricity Board in obtaining an inexpensive decorating kiln, and Mr. Scholefield was given an opportunity of making a practical experiment with an idea on which he had been working for some time.

The installation, the cost of which was less than half of the £3,000 that would have been needed for an electrically-fired tunnel kiln of comparable output, comprises a pair of rectangular kilns, each 2 ft. wide, 4 ft. 6 in. long and 3 ft. 6 in. high. They are set side by side and are used alternately in succession, one being loaded or unloaded while the other is being fired.

Each of the twin kilns is fed by a truck running on rails and the kiln door is built in firebrick on to the truck. The door has a special self-sealing joint which dispenses with the need for sealing with clammings.

There is a simple electronic control device, which can be pre-set to the required temperature, and an automatic cut-out which prevents over-firing. The control ensures that only one kiln at a time can be switched on, which means that by the use of the twin installation the load is kept constant, giving load factors of upwards of 90 per cent., with the consequent reduction in the price of the electricity consumed.

In order to achieve uniformity as far as possible throughout the kiln section, the electrical loading is staggered, with two bottom hairpin elements of 3,680 watts each, No. 2 element with 2,880 watts on one side and 3,680 watts on the other, No. 3 element with 2,800 watts on one side and 1,240 on the other, No. 4 with 1,240 watts on either side, and Nos. 5 and 6 both with 2,800 watts on either side.

This arrangement results in a section admirably suited to firing various colours, with layers of temperature ranging from 760° C. to 650° C., according to the position of the ware on the trucks.

Firing is on a six-hour cycle, which permits each truck to be loaded twice every 24 hours. The traditional skill is required in placing the ware on the

furniture of the trucks, but all that remains is to roll the trucks in and out of their kilns at six-hour intervals, a task which is performed at night-time by Spencer Stevenson's night watchman.

Each truck takes sixty to seventy dozen pieces of ware, and with the twin kilns in continuous operation seven days a week, the capacity of the Spencer Stevenson installation is 2,000 dozen pieces of ware weekly.

Mr. Spencer Stevenson, who has forty years' experience in the pottery industry, has expressed his complete satisfaction with the installation, and he hopes eventually to put in two more pairs of similar kilns, to provide a battery of six, with a capacity of 6,000 dozen pieces of ware weekly.

The advantages he cites are:

1. Continuous tunnel kilns are initially costly and have to be kept going even when there is no ware ready for decoration. They also require a shift system, and in the event of an electrical fault, a shut down of up to ten days is necessary for cooling, repairs and re-heating.

2. The new twin kilns are comparatively inexpensive to install and are much more flexible in use. They can be shut down at little cost in slack periods and a maintenance shut-down is a matter of hours rather than days.

3. Temperature settings can easily be altered for special jobs, or, if necessary, for part of production.

4. The twin kilns require comparatively little space, a factor of some importance in the layout for flow production of many small pottery factories.

5. The life of the furniture is increased by the absence of movement.

6. The new kilns have been found to give the ware a better "soak" bringing up the best colours and making the decoration more durable. In addition there has so far been a remarkable and inexplicable absence of crazing.

7. Fuel efficiency, though admittedly lower than that of continuous tunnel kilns, compares very favourably with the traditional coal-fired kiln. Each of the twin kilns has a maximum demand of 27 kW, average consumption during the six-hour cycle being 155 units at ·9d. per unit, against about 30 cwt. of coal at 69s. 10d. a ton used in firing 300 dozen pieces in the bottle kiln.

Mr. Spencer Stevenson is hoping that the new kilns can be adapted to glost and perhaps even to biscuit firing. Higher temperatures have been achieved but it is considered that the elements and structural materials require modification in design for continual operation at such temperatures. To achieve the 1,240-1,300° C. needed for biscuit firing would require a longer cycle of operation and a larger sized kiln.

At the request of a well-known manufacturer, Mr. Scholefield is already working on the design of a modified form of the new kiln for use for biscuit firing. The indications are that it will involve an increase in cubic capacity and a longer cycle of operation.

The possibility of success in this task has been considerably enhanced by the development by the Morgan Crucible Co. Ltd., of Neston, Cheshire, of the M.R.128 brick, which can be used for the construction of the firing face, dispensing with the firebrick face. This development promises a considerable reduction in fuel consumption in intermittent kilns and greatly improves the prospects of adapting the new-type kiln to glost and biscuit firing.

Mr. H. A. F. Caddell, manager of the North Staffordshire Sub-area of the Midlands Electricity Board, who has taken a close interest in the Spencer Stevenson installation, believes that the new kiln and the experiments now in progress to develop it, are of the utmost importance to the pottery industry, particularly from the point of view of the many small firms which are planning reconstruction and modernisation of equipment but are anxious to avoid heavy capital expenditure.

"For them," Mr. Caddell explains, "this installation is ideal, for they can begin with one pair of kilns at a comparatively small outlay and extend with additional pairs as and when capital is available.

"If present experiments in the firing of china biscuit by this method prove successful it means that almost any form of pottery can be fired. This would be a big step forward in the task of modernising the pottery industry, not to mention such considerations as the need for smoke abatement, of which the industry is

very conscious at the present time."

The Spencer Stevenson installation, which has now been in operation for six months, has attracted considerable interest in the industry. It has been seen by officials of Gibbons Bros. Ltd., the well-known kiln manufacturers, of Dudley, Worcs., who state that they intend to manufacture the new kiln in a range of sizes, some smaller and some larger than the Spencer Stevenson prototype.

BRITISH CERAMIC SOCIETY

Titles of papers appearing in the August, 1953, issue of the *Transactions of the British Ceramic Society* are as follows:

Reaction of Zinc and Zinc Oxide with Firebricks, by H. M. Richardson and G. R. Rigby.

The Electrical Conductivity of Spinels, by T. E. Bradburn and G. R. Rigby.

Fuel Utilisation and Heat Recovery in the Heavy Clay Industry with Special Reference to Roofing-tile Manufacture, by E. Rowden.

AMERICAN CERAMIC SOCIETY

Titles of papers appearing in the August, 1953, issue of the *Journal of the American Ceramic Society* are as follows:

Investigation of Gases Evolved During Firing of Porcelain Enamels, by D. G. Moore and Mary A. Mason, National Bureau of Standards, Washington, D.C.

Hydrothermal Synthesis of Quartz Crystals, by A. C. Walker, Bell Telephone Laboratories Inc., Murray Hill, New Jersey.

Relationship of Surface Structure of Glass to Residual Laminar Stresses, by W. C. Levengood and E. B. Butler, Libbey-Owens-Ford Glass Co., Toledo, Ohio.

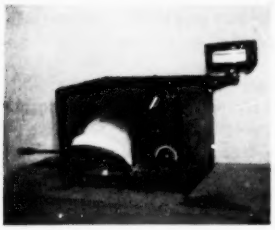
Effect of Partial Devitrification on the Electrical Resistivity of Sodium-bearing Glasses, by B. L. Joyner and W. C. Bell, Department of Engineering Research, North Carolina State College, Raleigh, North Carolina.

Chemical Analyses, Surface Area, and Thermal Reactions of Natural Graphite, and Refractoriness of the Ashes, by L. Mackles, R. A. Heindl, and L. E. Mong, National Bureau of Standards, Washington, D.C.

Permeability and Some Other Properties of a Variety of Refractory Materials—Part II, by G. B. Massengale, L. E. Mong, and R. A. Heindl, National Bureau of Standards, Washington, D.C.

TUMBLING MEDIA

A RECENT introduction in America has been the use of ceramic shapes for tumbling processes. Known in the U.S.A. as tumbling pebs, they are roughly triangular in shape and the thickness is about equivalent to half of the height from base to apex. They are available in the U.S.A. in several sizes and it is claimed that they do not cut quite so fast as the normal materials, but the uniform results and the longer life of the "pebs" make them a good proposition in most tumbling and deburring operations.



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The Egyptian Ceramic Industry

Part I—Raw Materials

by

M. Y. BAKR, M.Sc., B.Sc. (Hons.)

ABSTRACT: Egypt possesses all raw materials necessary for the ceramic industry, i.e., clays, kaolins, feldspars, and quartz. The clays in Egypt at present time are classified into: 1. Aswan clays, 2. Sinai clays, 3. Quena and Tabbin clays, 4. Kharga clays, 5. Moqattam clays, and 6. the Nile mud. The major sources of feldspars and quartz in Egypt are found in the district of Aswan. Some aspects of the geological origin of the most important local raw materials used for Egyptian ceramics are given. Careful studies have revealed that raw materials present in Egypt are suitable for use in ceramics.

Introduction

BEFORE the last war, all the high-grade raw materials (china and ball clays) were imported from Europe The rising prices of foreign raw materials, and their transport put our ceramic industry in front of the duty to seek for workable and easily transportable local raw materials. The author has, since 1947, occupied himself with the finding of the possibility of a substitution for the foreign clays and kaolins by local raw materials. These are found mainly in Aswan district where all the necessary raw materials are exploited.

Aswan clays are classified locally into white, red, and siliceous clays. They are found in the following regions[1]: Aswan-Gharb, Abu-el-Rish Bahari, Abu-el-Rish Gibli, and South of Aswan. The quarries of these ores are in the vicinity of the Nile, and more than 250 metres from the railways. They are either uncovered, i.e., open working, or in caves. The depth of the strata for use is about 3 metres and those unfit range from 1-4 metres. The means of transport from the quarries are animals and lorries to the Nile. The means of cutting are by axes and sometimes explosion.

Aswan Kaolins are found at Wadi-el-Heita, Sikket-el-Arud, and Khor-el-Dabaa.[1]

As a result of recent prospecting some new clay deposits have been found in Sinai, at Wadi-Budra and Abu-Zenima, which yield better raw materials.

There are also clay deposits in Quena, Tabbin, Kharga and Moqattam besides the Nile mud.

Feldspar is being presently produced in Aswan district at Gebel-Shairk Aswan, Sheikh-Haroon, and Nag'el Seil[1]. Also quartz occurs in the same district at Nag'el-Gezira.

We cannot differentiate easily between different kinds of raw materials by the chemical and rational analysis alone. The commercial possibilities of clays and their selection for industrial use can be determined, however, by studying their physical properties besides a knowledge of their chemical constitution.

The purpose of Part I of this article is to discuss the chemical and rational analysis of several Egyptian raw materials and to build a simple classification which covers all the raw materials based on the chemical, and rational analysis and geological aspects. Part II of this series of study deals with the physical properties of these raw materials.

Geology

The clays of Aswan district cannot be residual as the source rock is not found to underlie the deposits[1]. They are sedimentary and plastic.

TABLE I.—CHEMICAL ANALYSIS OF THE RAW MATERIALS: CLAYS AND KAOLINS

Sample No. and Source	Free SiO_2	Combd. SiO_2	Total SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	Loss on Ignition H_2O	Loss on Ignition CO_2	Loss on Ignition SO_3	Cl_2
1														
White Aswan clay	10·2	41·7	51·9	33·0	1·0	0·2	0·4	0·3	1·0	0·6	11·3	0·2	0·25	0·5
2														
Red Aswan clay	24·5	31·0	55·5	25·0	6·9	0·6	0·7	0·4	1·0	0·7	8·5	0·4	0·2	0·6
3														
Siliceous Aswan clay	66·0	12·6	78·6	9·5	1·4	0·9	0·6	0·1	1·5	1·5	3·5	0·2	0·6	1·1
4														
Aswan kaolin	14·4	38·0	52·4	30·1	1·5	0·7	0·8	0·4	2·0	0·2	11·0	0·35	0·25	0·21
5														
Sinai kaolin	4·4	45·2	49·6	36·0	0·8	0·1	0·3	0·1	1·0	0·3	12·0	0·1	0·2	0·15
6														
Quena clay	5·0	28·0	33·0	15·0	8·1	0·7	17·5	2·0	1·0	1·0	6·0	13·4	0·6	1·2
7														
Kharga clay	26·0	28·0	54·0	22·5	6·5	0·3	1·0	0·3	2·0	1·6	9·0	0·6	0·3	1·7
8														
Florida, U.S.A.	—	—	46·95	36·75	0·8	0·18	0·15	0·2	0·24			14·95		—
9														
English ball clay	—	—	47·51	34·14	1·0	1·3	0·18	—	1·64	0·44		12·75		—
10														
Theoretical clay	—	—	46·5	39·4	—	—	—	—	—	—		14·0		—

TABLE 2.—CHEMICAL ANALYSIS OF THE RAW MATERIALS: FELDSPARS

Source	Sample No.	Free SiO_2	Combined SiO_2	Total SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Loss on Ignition
Gebel-Shairk	1	4·5	62·0	66·5	17·5	0·2	—	—	14·5	1·2	0·3
Aswan	2	3·0	62·0	65·0	17·9	0·2	0·1	—	15·5	0·8	0·4
	3	7·1	60·0	67·1	17·3	0·4	0·1	0·1	13·5	1·3	0·4
	4	13·5	55·0	68·5	16·7	0·5	0·3	0·2	12·6	0·8	0·5
Nag'el Seil	5	17·0	55·0	72·0	14·5	0·9	0·6	0·2	10·1	1·3	0·3
	6	18·2	53·5	71·7	14·0	1·4	0·5	0·3	9·5	2·1	0·5
	7	29·0	45·0	74·0	13·0	2·2	0·4	0·4	8·5	0·9	0·6
Sheikh Haroon	8	28·5	46·0	74·5	12·0	3·1	0·8	0·3	7·5	1·2	0·8
	9	31·0	33·0	64·0	22·5	2·5	0·9	0·6	3·5	2·4	3·6
American	10	—	—	70·6	16·57	0·13	0·5	—	8·63	3·03	0·43
English	11	—	—	65·73	19·01	0·23	0·28	0·27	11·07	2·21	0·36
Theoretical	12	—	—	64·7	18·4	—	—	—	16·9	—	—

TABLE 3.—CHEMICAL ANALYSIS OF THE RAW MATERIALS: QUARTZ

Source	Sample No.	SiO_2	AL_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	Loss on Ignition
Nag'el Gezira	1	99·7	0·25	—	—	0·1	—	—	—	—
American	2	99·65	0·11	0·02	—	0·12	—	—		0·23
English	3	98·47	1·02	0·04	—	0·02	—	0·04	0·11	0·13

TABLE 4.—RATIONAL, CALCULATED, AND EXPERIMENTAL ANALYSIS OF THE RAW MATERIALS: CLAYS AND KAOLINS

		1	2	3	4	5
	Sample	Rational Analysis			Calculated	Experiml.
Source	No.	Clay Subst.	Feldspar	Quartz	Quartz	Quartz
White Aswan clay	1	83	6·5	10·5	8·5	10·2
Red Aswan clay	2	66	7·0	27·0	20·8	24·5
Siliceous Aswan clay	3	30	10·0	60·0	56·5	66·0
Aswan kaolin	4	67	15·	18·0	11·1	14·4
Sinai kaolin	5	89	6·5	4·5	3·4	4·4
Quena clay	6	75	10·	15·0	9·0	5·0
Kharga clay	7	56	15·	29·0	16·1	26·0

The material worked for kaolin in the Aswan district occurs beneath the "Nubian Sandstone" series and varies in composition according to locality. Thus, while in some places it may have its origin in altered granite, in others this may be as altered schist.[3]

Sinai clays known in Egypt as Sinai kaolins are residual and poor in plasticity. It has been found that the kaolin beds in Sinai always occupy a fixed horizon, directly above the fundamental granitic series, the feldspar constituent of which is doubtless the contributing element of kaolin, modified by weathering and alteration.[4]

The rocks around Quena are mainly represented by shales, marls, and limestones. It is composed of an intimate mixture of very fine clays and calcium carbonate which has been washed out of the limy hills at the border of the Nile valley.[5]

Feldspar is worked in the Aswan district from pegmatite dykes as it is the most common dyke rock besides coarse and fine granites there.[3,4] The dyke is generally very coarse-grained intergrowth of quartz, and buff orthoclase feldspars, the latter being the more abundant constituent. Sometimes quartz is almost entirely absent, so that the dykes are practically formed of orthoclase. In others, dykes of almost pure vitreous quartz predominate.

Discussion of the Results

Tables 1, 2, 3 and 4 show the chemical (ultimate) analysis and rational analysis of seven samples of clays and kaolins; nine samples of feldspars and one sample of quartz obtainable from areas of Egypt which produce the major output of ceramic raw materials, have been compared with foreign materials.[7]

Chemical analysis shows the constituents of a raw material only in terms of oxides. It makes known the undesirable constituents of the clay for the potter such as iron, alkalis, and alkaline earths. Chemical analysis alone is not sufficient for the complete conception of the material occurrence of the various constituent in a mineral. Thus the rational analysis will complete what is lacking and impossible to obtain by chemical analysis. The rational analysis is used to divide the mineral constituent of a clay into flint (quartz), feldspar and clay substance.

From Table 1 and 4 it can be seen that although there is a significant difference in the percentage of Al_2O_3 and K_2O, between the samples of clays and kaolins, the rational analysis would probably show that samples No. 4 and 7 contain feldspar as an admixture which would account for the greater K_2O content. Sample No. 4 is known locally as Aswan kaolin and sample No. 7, Red Kharga clay. The lower Al_2O_3 content of sample No. 3 could be accounted for the presence of less kaolinite and high-free silica and is known locally as "Siliceous Aswan Clay." Sample No. 6 has the highest percentage of lime, it is regarded as calcareous clay and is known locally as Quena clay.

A general comparison between the ore samples show that samples No. 1 and No. 5 are the best. As rational analysis shows that both contain highest percentage of clay substance

(more than 80 per cent) and the lowest percentage of quartz and feldspar. Sample No. 1 resembles in its chemical composition the ball clays and is known locally as "White Aswan Clay" and sample No. 5 is similar to china clay and is known locally as Sinai Kaolins.

From Table 2 it can be seen also, that the richest deposits of feldspar are found in Gebel-Shairk Aswan (Feldspar No. 1, 2, 3, and 4). These are the best samples for industrial use because they possess the following properties: 1. Low iron content; 2. Maximum alkali content; and 3. Minimum free silica. Their chemical composition agrees exactly with the theoretical value of orthoclase. These deposits of Gebel-Shairk Aswan have already been exploited for a long time and unfortunately they are exhausted (Feldspar No. 1 and 2); however, some new deposits have been recently found (Feldspar No. 3 and 4).

Next to the above feldspars are those of Nag'el-Seil (Feldspar No. 5, 6, and 7). They have somewhat high content of free silica and iron oxide, and less alkalis.

Feldspar No. 9 is of low grade type and it may be regarded as an altered one for its low percentage of potash and high alumina content and free silica.

The quartz deposit at Aswan in Nag'el-Gezira is a very pure white hard deposit from the chemical point of view, Table 3.

The following gives a general idea of the amount of feldspars used by the author in Egyptian types of ceramic bodies, earthenware, 20-30 per cent.; sanitary ware, 25-30 per cent.; semi-vitreous ware, 20-25 per cent, and white ware like American hotel china, 15-20 per cent.

Classification of Egyptian Clays and Kaolins

From a knowledge of the determination of the above mentioned chemical and rational analysis, and geological aspects, the following classification is based. (Table 5.)

Alumina

1. High ... ... >30%
2. Relatively high 15-30%
3. Low ... ... <15%

Iron

1. High ... >1·5%
2. Low ... <1·5%

Free Silica

1. High ... ... >30%
2. Relatively high 15-30%
3. Low ... ... <15%

Free Silica

Silica is the most important ingredient of ceramics. The total amount of silica as found by chemical analysis comprises colloidal silica, free silica, and combined silica altogether. The determination of the free silica by the method described by Trostel and Wynne[5] is very useful in the commercial use of refractory clays. (Table 4 col. 5.)

It is clear that the free silica calculated from chemical analysis (Table 4 col. 4) depends upon the suggestion that we have a kaolinite group and neglecting other mineral groups that may be present.

Also in the rational analysis we suggest that we have a kaolinite group (Table 4 col. 3).

But in the free silica, determined experimentally, we have no such suggestions. That is why I suggest only the separate chemical analysis of quartz determination as a reliable method for free silica determination. This method was checked experimentally by X-ray analysis, thermal analysis by the author and it was found satisfactory for the determination of free silica in Egyptian clays and kaolins.

So if we summarise the three percentages, we can say that in high-grade clays, they agree, e.g., samples No. 1 and 5 but in low-grade clays they differ markedly, e.g., samples No. 4 and 7.

Iron Content

The colour chemistry of clays is linked principally to the iron content present. A high iron content in clays and kaolins reduce their value considerably, besides it acts as a powerful flux if the clay is heated in a reducing atmosphere.

Alumina Content

The alumina content of clay is of a still more important significance, it increases the refractoriness of the clay. Thus clay rich in alumina, is apparently more viscous and it retains its shape when heated to softening point.

TABLE 5.—CLASSIFICATION OF EGYPTIAN CLAYS AND KAOLINS

1. ASWAN CLAYS.

A. Secondary or transported clays.

i *High in alumina* ... (>30 %)
(a) Low in iron ... (<1·5 %)
(b) Low in free silica (<15·0 %)
They are known as "White Aswan clays" (e.g., Sample No. 1).

ii *Relatively high in alumina* ... ... (15-30 %)
(a) High in iron ... (>1·5 %)
(b) Relatively high in free silica ... ... (15-30 %)
They are known as "Red Aswan clays" (e.g., Sample No. 2).

iii *Low in alumina* ... (<15 %)
(a) Low in iron ... (<1·5 %)
(b) High in free silica (>30 %)
They are known as "Siliceous Aswan clays" (e.g., Sample No. 3).

B. Primary or residual clays.

High in alumina.
(a) Low in iron.
(b) Low in free silica.
They are known as "Aswan kaolins" (e.g., Sample No. 4.)

2. SINAI CLAYS.

Primary or residual clays.

High in alumina.
(a) Low in iron.
(b) Low in free silica.
They are known as "Sinai kaolins" (e.g., Sample No. 5).

3. QUENA CLAYS.

Relatively high in alumina.

(a) High in iron.
(b) Low in free silica.
They are known as "Calcareous clays" (e.g., Sample No. 6).

4. KHARGA CLAYS.

Secondary or transported clays.

Relatively high in alumina.
(a) High in iron.
(b) Relatively high in free silica.
They are known as "Red Kharga clays" (e.g., Sample No. 7).

Classification Table 5.

1. *White Aswan Clays* (*Sample No.* 1)

Pure secondary clays are known locally as "ball clays" or "White Aswan clays" in Egypt. In their chemical composition, they do not differ greatly from the best Egyptian kaolins except that they often contain a rather larger proportion of alkalis and iron and a lower percentage of alumina. They are more vitreous when fired but do not burn white as the kaolins. They are used in the manufacture of table ware porcelain. The author found that the "White Aswan clays" possess all the necessary properties for fine ceramic if they are well washed.

2. *Red Aswan Clays* (*Sample No.* 2), *or Vitrifiable Clays*

One of the important disadvantages of "Red Aswan clays" is their deleterious effect on the colour of the fired body. They contain a variety of impurities, the kind and amount of these impurities exert a tremendous effect on the physical properties of the clay. High percentage of iron renders them more or less unsuitable for the manufacture of fine ceramic products. They are used in the manufacture of stoneware, sanitary ware, tiles and vitrified bricks.

3. *Siliceous Aswan Clays* (*Sample No.* 3)

They have the highest percentage of free silica and the lowest percentage of clay substance, besides a low percentage of iron. They are used as quartz when it contains a very small percentage of iron, lime and alkalis in fine ceramics.

4. *Aswan Kaolins* (*Sample No.* 4)

Residual clays at Aswan are called "Aswan kaolins" in Egypt. They contain more than 10 per cent. free silica and greater percentage of fluxing oxides than Sinai kaolins. They have in most cases to be purified and washed before being used in fine ceramics.

5. *Sinai Kaolins* (*Sample No.* 5)

Very pure residual clays in Sinai known in Egypt as "Sinai kaolins". They contain very low percentage of free silica, better coloured both in raw and fired material but poor in plasticity. They appear in chemical properties similar to china clay except in the percentage of alumina which is low. They have good casting properties and are used by the author in the porcelain and insulator industry.

6. *Quena Clays* (*Sample No.* 6), *or Calcareous or Fusible Clays*

They are found also at Tabbin. They

have a high percentage of lime, more and stronger fluxes than the Red Aswan clays. They are used in Quena and Tabbin for making ordinary pottery and in the manufacture of bricks.

7. *Red Kharga Clays (Sample No. 7)* Impure secondary clays at Kharga. They have high percentage of iron and free silica. They are used at Kharga for making ordinary pottery and in bricks.

Acknowledgment

Thanks should be extended to Prof. Dr. M. A. Kassem of Metallurgy and Chemistry Department, Faculty of Engineering, Alexandria University for his constant encouragement and advice.

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PLANT AND MACHINERY CATALOGUE

PRIOR to the war, it may be recalled, George Cohen and Co. Ltd. used to issue regular editions of their catalogue of new and second-hand machinery and plant which they had in stock. This catalogue was a very handy guide to the availability of equipment and was usually to be found in most engineers' offices. The restrictions on the use of paper during the war, naturally put an end to the publication.

This week we were both surprised and pleased to see that it has been revived and a copy of the first issue appeared on our desk a few days ago. An accompanying note informs us that it will be published several times a year in future.

POTTERY CORNER

The Applied Heat Company Ltd., Elecfurn Works, Watford By-Pass, Watford, Herts, inform us that they have now installed in a part of their premises to be known as "Pottery Corner," Grafton kilns for the firing of ware produced by student and artist potters whose output is not sufficient to warrant the installation of their own kilns.

In a long association with artist potters, the company say they have always met the complaint that few facilities are available for them to get their ware fired. Art schools in most cases find it hard enough to cope with all the ware produced by their own students and, much as they would like to help, are obviously not in a position to do much.

"Pottery Corner" offers to such potters within reasonable distance of Watford, firing facilities in modern electric kilns for biscuit glost and decorating at reasonable cost. Those wishing to take advantage of this offer should write or phone with a view to bringing their ware for firing to:—"Pottery Corner," Elecfurn Works, Watford By-Pass, Watford, Herts. (Watford 6091).

Mr. P. Bailey Retires.—Ridgway and Adderley Ltd. announce that Mr. Philip Bailey has retired as general manager of Globe Pottery, Shelton, and has also resigned his directorships of the Lawley Group Ltd., and its associated companies. Mr. Bailey is one of the original members of the Wages Advisory Committee of the British Pottery Manufacturers' Federation, and also a member of the Joint Industrial Council of the pottery industry and of many Federation committees and associations, and is chairman of the Vitrified Manufacturers' Association.

Technical Tourists.—The pottery and glass and ceramics industries in Edinburgh co-operated in a scheme sponsored by the Junior Chamber of Commerce to publicise the City's industries over the period of the Festival of Music and Drama. Industrial concerns opened their plants to visitors on specified days, to allow technically-minded tourists an opportunity to see the City industries at work. Among the firms co-operating were Edinburgh and Leith Flint Glass Works and A. W. Buchan and Co. Ltd.

NEW COLOUR-CORRECTED MERCURY FLUORESCENT LAMPS

A RANGE of new Osram colour-corrected mercury vapour discharge lamps became available on 1st September, in 80-watt and 125-watt ratings. These lamps employ an entirely new fluorescent powder and their colour appearance and colour rendering properties show a substantial improvement over their predecessors. The powder itself has an attractive white body colour and provides an increased red ratio of 7 per cent. Its improved temperature stability has enabled the outer bulbs to be reduced in size to that of the standard Osram mercury lamps of the same wattages.

The new Osram 125-watt lamp is available with either the G.E.S. or the three-pin bayonet cap. The 80-watt lamp has a three-pin bayonet cap. Thus these better-colour lamps can be used in place of the earlier mercury fluorescent types or, by virtue of their reduced bulb size, substituted for 80-watt or 125-watt mercury pearl lamps.

The list prices of both Osram mercury-fluorescent lamps have not changed from £2 8s. 6d. for the 80 watt and £2 19s. 0d. for the 125-watt size.

THE NICKEL BULLETIN

THE NICKEL BULLETIN, July, contains abstracts of an important series of papers presented at the Washington Conference on Magnetism held last year. Information on the magnetic characteristics of nickel and of nickel alloys of both high-permeability and permanent-magnet types is given in a number of these papers. Various papers from other sources on magnetic alloys are also reviewed.

The section on heat-resisting materials includes an abstract of the results of a study at the National Physical Laboratory of the influence of cyclic stress and temperature on the creep behaviour of alloys of the Nimonic series, and of a report on hardening phenomena occurring in austenitic chromium-nickel steels at 475° C. Abstracts on corrosion-resisting steels refer to research on the amount of oxygen found on the surface of passive stainless steels and the thickness of oxide film to produce passivity, and to comparative tests of the resistance of titanium, zirconium and stainless steels to organic compounds.

Recent papers on spheroidal-graphite cast iron are summarised and attention is drawn to a revised British Standard specification for condenser-tube alloys covering copper, brass, bronze and copper-nickel alloys.

The issue marks the completion of twenty-five years continuous publication of *The Nickel Bulletin* and includes a short review of the aims and scope of this publication.

NEW DIE GRINDER KIT

IN introducing a new die grinder kit (type DG1), Wolf Electric Tools Ltd., are satisfying the long felt need for a handy versatile tool at low cost to undertake a great variety of jobs in every tool room, machine shop and maintenance department. The extremely powerful driving unit which possesses abundant speed and power, has a capacity for grinding wheels up to 1½ in. dia. × ⅛ in. and has a speed (running light) of 16,000 r.p.m.

Its nett weight is 5 lb.; although primarily intended as a portable tool, it may with advantage be mounted in a bench clamp stand for stationary use.

Dust-sealed ball bearings are used throughout and the double pole switch is of ample capacity and is fitted with a retaining button. Armature and field windings are enamelled and double silk covered copper wire, and the armatures are dynamically balanced to precision limits by electronic methods.

The complete kit comprises the high-speed DG1 grinder with 10 ft. of three-core T.R.S. cable, spare set of carbon brushes, a carefully chosen set of mounted points, grinding wheels, and felt bobs and arbors completely housed in a specially designed steel carrying case. This useful outfit provides an efficient method for grinding down contours, correcting inaccuracies in dies, light profile grinding, retouching taps, cutters and forming tools, etc. A wider selection of rotary files and milling cutters for use on non-ferrous metals is available to suit special requirements.

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THE BRITISH CERAMIC SOCIETY

The Autumn Meeting of the **Building Materials Section** of the Society will be held in London on 19th and 20th November. Papers will be read by Mr. M. E. C. Stedham on the production of expanded clay aggregates, and by the President (Mr. A. J. C. Watts) and Mr. Butterworth on the use of pulverised-fuel ash in brickmaking. On 20th November, members have been invited to visit the Building Research Station at Watford. A dinner to be held at the Dorchester Hotel on 19th November, to which all Sections are invited, has also been arranged.

The Autumn Meeting of the **Refractory Materials Section** will be held in London on the same dates. On 19th November there will be a symposium on casting-pit refractories at which papers will be presented by both users and manufacturers. On the morning of 20th November papers will be read on insulating refractories and on the high-temperature properties of chrome-magnesite materials.

BRITISH VISQUEEN LTD.

CONSTRUCTION has started at Stevenage, Hertfordshire, of the headquarters and factory of British Visqueen Ltd., the company formed jointly by Imperial Chemical Industries and the Visking Corporation of Chicago, U.S.A., to manufacture polythene film in Britain.

Authorised capital of British Visqueen Ltd. is £240,000 in £1 shares. Two-thirds will be held by I.C.I. and one-third by Visking.

The chairman of British Visqueen Ltd. will be Mr. J. C. Swallow (who is chairman of the Plastics Division of I.C.I.) and the managing director will be Mr. N. J. Travis (who is at present on the staff of I.C.I. Plastics Division); other directors are Mr. A. F. Gawler, Mr. H. C. Raine and Dr. J. E. Sisson (all of I.C.I. Plastics Division) and Mr. F. C. Howard and Mr. A. T. Peterson (for the Visking Corporation). Polythene was discovered in I.C.I. laboratories in 1933 and I.C.I. has pioneered its manufacture in film form in Great Britain.

Polythene film is transparent, tough, inert, moisture and waterproof and is used for packaging many commodities including foodstuffs, pharmaceuticals, chemicals, electrical and metal components, textiles, machinery, and so on.

THE PLATINUM METALS EXHIBITION

THE Institution of Metallurgists announce that H.R.H. The Duke of Edinburgh has graciously consented to open their Platinum Metals Exhibition at Grosvenor House on Monday the 19th October, 1953. The exhibition is being held to mark the Triple Jubilee of the British Scientist, William Hyde Wollaston's announcement of his discovery of the precious metal palladium.

The exhibition which will be open to the public from Thursday, 22nd October to Saturday, 24th October, will show the vital part played by the platinum metals in science and industry today.

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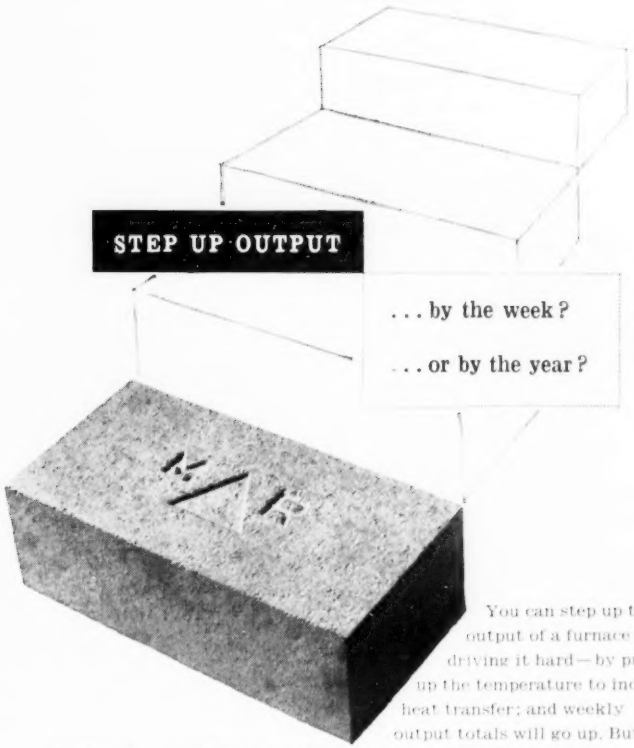

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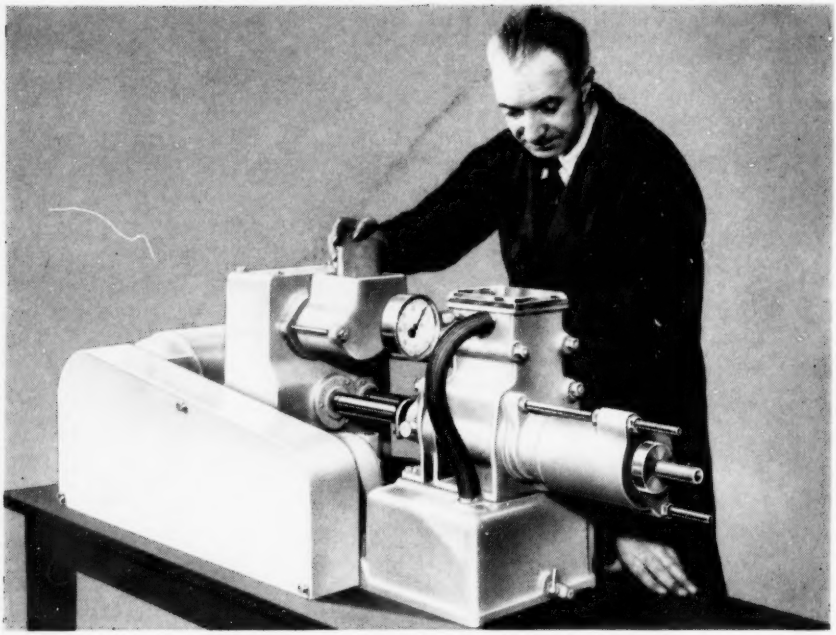

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